NICKEL

By Peter H. Kuck

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Stainless steel accounted for more than 60% of primary nickel consumption in the world. In the United States, however, this percentage was only 46% because of the relatively large number of specialty metal industries in the country. Specialty uses included superalloys and related aerospace alloys, high-temperature nickel-chromium alloys, electrolytic plating, electroless plating, cupronickel alloys, and naval brasses. Manufacturers of rechargeable batteries have been using increasing amounts of nickel metal foam. The foam is produced in only four countries—Canada, China, Russia, and the United Kingdom.

Nickel in excess of 8% is needed to produce the austenitic microstructure in 300-series stainless steels. The nickel content of some austenitic grades can be as high as 22%. Duplex (ferritic-austenitic) steels generally contain only 2.5% to 5.0% nickel. Sometimes, smaller quantities of nickel (0.2% to 3.8%) are incorporated into low alloy steels to improve their resistance to corrosion.

Legislation and Government Programs

Decontamination of Radioactive Nickel Metal.—For more than a decade, the U.S. Department of Energy (DOE) has been exploring ways of reusing nickel metal scrap contaminated with trace amounts of natural and manmade radioactive isotopes. On November 15, 2002, the Oak Ridge Operations office of the DOE issued a general solicitation, inviting qualified companies in the metals and nuclear industries to participate in its nickel decontamination and recycling program (Marley, 2002; U.S. Department of Energy, Oak Ridge Operations, 2002§[1]). The decontaminated nickel would only be used in government or commercial nuclear industry applications because of current DOE policies and the absence of national standards controlling the release of decontaminated metal to scrap processors and consumers. The U.S. Nuclear Regulatory Commission (NRC) was developing the required regulatory standards with the help of the National Institutes of Health, but a number of issues still needed to be resolved.

The DOE had about 15,700 metric tons (t) of nickel scrap in varying stages of decontamination at the end of 2002. About 9,700 t of volumetrically contaminated nickel ingots was stored at the DOE uranium enrichment facility in Paducah, KY. "Volumetrically contaminated" describes metal that has radioactive contamination dispersed throughout the mass of the metal as opposed to a surface coating of contamination. The United States Enrichment Corporation currently operates the gaseous diffusion plant at Paducah, but the DOE has retained a large part of the original Paducah defense nuclear site and has been storing previously generated wastes there. About 3,600 t of shredded nickel scrap was stored at the closed DOE uranium enrichment facilities in Oak Ridge, TN. Part of the Oak Ridge facilities—the K-25 site where the gaseous diffusion plant was built—has been transformed into the East Tennessee Technology Park. Ongoing demolition activities at Oak Ridge were expected to generate an additional 2,400 t of shredded nickel metal scrap. The huge K-25 building shell was not scheduled for demolition until 2008. Future demolition activities at Oak Ridge, the shuttered facility at Portsmouth, OH, and the operating Paducah facility could generate another 21,000 t of shredded nickel scrap. The principal contaminants in the Oak Ridge and Paducah nickel are technetium-99 (a low-energy beta-emitter with a half-life of 211,000 years) and uranium-235. Trace quantities of neptunium (atomic number 93), plutonium (94), and americium (95) also are present in much of the scrap (Marley, 2002; U.S. Department of Energy, Oak Ridge Operations, 2002§).

In 1993, DOE accelerated its efforts to decontaminate and recycle radioactive nickel scrap that had accumulated at U.S. defense nuclear facilities since World War II. More than 6,000 t of nickel metal had been used for gaseous diffusion barriers. Researchers found that both melt refining and conventional electrorefining could remove uranium and several transuranic elements from the nickel but that neither method was able to significantly reduce the technetium-99 (Tc^{99}) contamination. Five years later, in 1998, Manufacturing Sciences Corporation, Inc. (MSC) demonstrated that advanced electrorefining techniques could be used to reduce the Tc^{99} contamination to levels below 1 Becquerel per gram (Bq/g). MSC has proposed that the NRC adopt a standard of 1 Bq/g for the release of recycled radioactive metal. Tc^{99} contamination in unprocessed Paducah nickel ingots reportedly ranges from about 200 to 700 Bq/g (U.S. Department of Energy, Office of Environmental Management, 2001, p. 1-6). MSC is a subsidiary of British Nuclear Fuels Limited, which had a $238 million contract to decontaminate and decommission three buildings at the K-25 site.

The North American metals industry, concerned about public perception, voiced its objections about the MSC program to the DOE. The North American metals industry has had to deal with a number of incidents in which lost or stolen radioactive material inadvertently entered the commercial recycling stream. Similar incidents have occurred in Europe and South America. Cleanup of a radioactively contaminated meltshop is an extremely costly proposition. The industry opposition, spearheaded by the American Iron and Steel Institute (AISI) and the Metals Industry Recycling Coalition, also was focused on the presumption that the general public would misconstrue radiation safety levels and confuse safe stainless steel made from decontaminated nickel with hazardous steels inadvertently contaminated with cobalt-60 or other common commercially available radioisotopes—hurting household purchases of stainless steel products.

[1]References that include a section mark (§) are found in the Internet References Cited section.

On January 12, 2000, the Secretary of Energy placed a moratorium on the free release of any volumetrically contaminated material from DOE facilities to recyclers or other processors. The action was taken in response to the concerns of the scrap metals industry, consumer protection groups, and Congress. Seven months later, on July 13, 2000, the moratorium was expanded to include all radioactively contaminated materials. The DOE and the NRC allowed MSC to continue to investigate alternative uses for radioactive nickel scrap under a restricted release scenario. One use under consideration was the production of nickel-bearing stainless steel sheet and the fabrication of stainless steel containers within the confines of the National Laboratories. The containers would be used to store high-level radioactive waste for long periods of time in NRC-licensed repositories (U.S. Department of Energy, Office of Environmental Management, 2001, p. 3).

In 2003, the DOE awarded a $1.8 billion contract to Bechtel Jacobs Company LLC to accelerate cleanup efforts at Oak Ridge. The accelerated cleanup approach was the result of an agreement reached in 2002 among the DOE, the U.S. Environmental Protection Agency (EPA), and the State of Tennessee (U.S. Department of Energy, 2003).

National Toxicology Program.—The U.S. Department of Health and Human Services (DHHS) has been collecting and evaluating evidence on the toxicity and carcinogenicity of nickel metal and its alloys for more than 8 years. The ongoing scientific review was being carried out as part of the National Toxicology Program (NTP). The NTP is funded by the National Institute of Environmental Health Sciences under various congressional mandates.

On December 11, the DHHS released its updated and expanded report on carcinogenicity to the public. This publication—the 10th Edition of the Report on Carcinogens—contains an updated section on nickel compounds and metallic nickel. The report recommends that metallic nickel metal be treated as a "reasonably anticipated human carcinogen." The recommendation was based largely on evidence presented to the NTP Board of Scientific Counselors at a special hearing held in Washington, DC, in December 2000. The Board comprised scientists from both the public and private sectors and provides primary scientific evidence to the NTP Executive Committee.

Nickel alloys were specifically omitted from the 10th edition listings. The Board decided that nickel alloys should not be listed as potential carcinogens without more conclusive research and test data. Information compiled by the Nickel Producers Environmental Research Association (NiPERA) indicates that two alloys with the same nickel content can have completely different nickel release rates and, thus, different levels of carcinogenicity. The Board also was concerned about lumping the myriad nickel alloys used by the public into three or four categories and then making blanket statements about those categories.

Many nickel compounds were known previously to be human carcinogens. Nickel acetate, nickel carbonate, nickel carbonyl, nickel hydroxide, nickelocene, nickel oxide, and nickel subsulfide were all listed in the First Annual Report on Carcinogens. The initial listing was based on a large body of scientific evidence supporting the concept that the divalent nickel ion is carcinogenic. Some evidence suggests that relatively insoluble metallic nickel and nickel alloys are less likely to be a carcinogenic hazard than nickel compounds that release proportionately more nickel ion. Evaluators for the International Agency for Research on Cancer have pointed out that the carcinogenicity of nickel compounds depends not only on their capacity to release ionic nickel, but also on factors that cause nickel ions to concentrate at critical tissue sites within the human body. These complex interactions make it difficult to predict with any certainty the relative carcinogenic hazard posed by a specific nickel compound without a full understanding of exposure conditions (U.S. Department of Health and Human Services, 2002).

Environmental Programs.—The Portable Rechargeable Battery Association, a nonprofit trade association comprising about 90 manufacturers, distributors, assemblers, users, and sellers of small rechargeable batteries, continued to expand its nationwide battery collection and recycling system. The nonprofit, public service recycling program was being administered by Rechargeable Battery Recycling Corporation (RBRC) of Atlanta, GA. RBRC was supported by more than 285 manufacturer/marketer licensees and a network of 26,000 collection locations across Canada and the United States. The bulk of the spent nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries was being shipped to a pyrometallurgical reclamation facility at Ellwood City, PA. The facility was operated by the International Metals Reclamation Co., Inc. (Inmetco) (a subsidiary of Inco Limited).

New Coinage.—In 1999, the European Union (EU) and the United States began issuing new coinage after years of preparation. A significant part of the general public and most coin collectors were very enthusiastic about the new issues. Analysts of the world numismatic market have deemed both the EU and U.S. programs a huge success despite some setbacks. Some sectors of the public remained concerned that hypersensitive individuals could contract nickel dermatitis by handling the new coins that had cupronickel components.

Commemorative Quarters.—The U.S. Mint produced 3.31 billion quarters (25-cent coins) in 2002, down from 4.81 billion in 2001. The cupronickel-cladded coins were part of the popular 50 State Quarters™ Program launched in December 1998. A total of 19.02 billion quarters was minted between December 1998 and December 2002. Between 40 billion and 60 billion quarters will have been minted when the program ends in 2008. The five States honored in 2002 were Tennessee, Ohio, Louisiana, Indiana, and Mississippi (in order of minting). Since each coin weighs 5.67 grams (g) and contains 8.33% nickel, the total quantity of nickel ending up in the five commemoratives released in 2002 was about 1,570 t.

The Golden Dollar and Proposed Louisiana Purchase Nickel Series.—The new dollar coin has been less popular than the State quarters. The U.S. Mint began releasing the new golden dollar coin on January 27, 2000. A total of 1.42 billion coins was minted between January 2000 and December 2001. An additional 7.6 million were made in 2002. The dollar coin has an overall composition of 88.5% copper, 6.0% zinc, 3.5% manganese, and 2.0% nickel. Each coin weighs 8.1 grams and costs about 12 cents to produce. The coin is cladded with pure copper sandwiched between and metallurgically bonded to outer layers of manganese brass. The manganese brass cladding contains 4% nickel. The U.S. Mint was making a special effort to market the new dollar to collectors (U.S. Mint, 2002§). The coin honors the Louisiana Purchase of 1803 and the subsequent expedition of Lewis and Clark to explore the new trans-Mississippian territory (U.S. Mint, 2003§).

The U.S. Mint was planning to modify the Jefferson 5-cent coin in 2004 and 2005, again in commemoration of the Louisiana Purchase and the expedition of Lewis and Clark (Public Law 108-15). Two separate designs of the new Jefferson nickel were to be released in 2004 (Foley, 2003). The coins will be solid cupronickel.

Euro Coinage.—On January 1, 2002, 12 member countries of the EU began using a common coinage. Three members of the EU—Denmark, Sweden, and the United Kingdom—chose not to participate in the initial switchover. On February 28, the old currencies of the 12 participating countries ceased to be legal tender (European Central Bank, 2002). Coin production began in May 1998 so that the 50 billion coins needed for conversion would be available by the January 1 deadline. The European Central Bank (ECB) authorized an initial minting of 49.8 billion coins. Germany was authorized 17.0 billion coins; France, 7.5 billion; Italy, 7.2 billion; Spain, 7.1 billion; the Netherlands, 2.8 billion; and the seven other countries combined, 8.2 billion (European Central Bank, 2001b§). The obverse side of each denomination shows the coin's value and a common European design. The reverse side shows a national design chosen by the minting country, with the national design surrounded by 12 stars—one star for each member country. Any coin can be used in any member country, irrespective of the national design on the reverse side (European Central Bank, 2001a§).

Only the €1 and €2 coins contained nickel. The ECB decided not to have nickel in the six lower (and more numerous) denominations because of concerns from some sectors of the public about nickel dermatitis. When the exchange began, the national central banks had 4.8 billion €1 and 2.7 billion €2 pieces containing more than 11,000 t of nickel in stock (Plumail, 2001; European Central Bank, 2001a§). The €1 coin weighs 7.50 g and contains 14.89% nickel; the €2 coin, 8.50 g and 15.35% nickel. The total amount of nickel in the new euro coinage would then be 5,360 t plus 3,520 t, or a total of 8,880 t (CRU International Limited, 2002).

Some of the old coins of the 12 countries contained significant nickel and were highly valued as scrap because the alloy composition of each denomination was well known. In the case of the Netherlands, for example, the 10-cent, 25-cent, f.1, and f.2.5 pieces were all pure nickel. Four French denominations were also 100% nickel—the 50-centime and the F1, F2, and F5 pieces. Several other coins contained 25% or more nickel, including the S10 of Austria, the F10 of France, and the DM1, DM2, and DM5 pieces of Germany. The national treasuries have been encouraging their citizens to turn in long-hoarded coins for recycling. Individual treasury projections of coin returns ranged from 50% to 70% (CRU International Limited, 2002).

National Defense Stockpile.—There has been no nickel in the National Defense Stockpile since 1999.

Exploration

Duluth Complex of Minnesota.—Several mining companies had active exploration projects in the Duluth Complex of northeastern Minnesota. The companies were encouraged by the increase in the price of nickel during 2002 and the positive long-term outlook for consumption of nickel and coproduct platinum-group elements (PGE). The Duluth Complex covers some 5,000 square kilometers (km^2) of territory in St. Louis, Lake, and Carlton Counties. The complex comprises about 40 separate sheet-like or cone-like intrusions, which produced rock types with a wide range in composition from anorthosite to ferrogabbro and troctolite. The complex is associated with the midcontinent rift system of Middle Proterozoic age and is 1.1 billion years old (Mining Journal, 1998). Most of the exploration has focused on the western edge of the complex where it intrudes the Mesabi iron range and the younger Virginia slate. The nickel and PGE are associated with copper sulfide mineralization. The principal ore minerals are chalcopyrite ($CuFeS_2$), cubanite ($CuFe_2S_3$), pentlandite [$(Fe,Ni)_9S_8$], and pyrrhotite ($Fe_{1-x}S$) (Sims and Carter, 1996, p. 92-93).

Birch Lake Project.—Lehmann Exploration Management Inc. of Minneapolis, MN, was managing an advanced stage exploration project at Birch Lake Reservoir for the Beaver Bay Joint Venture. The Beaver Bay property is about 10 kilometers (km) east of the town of Babbitt in St. Louis County and less than 2 km east of the contact between the complex and the Biwabik iron formation. The venture has spent at least $4.7 million on the project to date (Lehmann Exploration Management Inc., 2003§). In November, Franconia Minerals Corporation signed an earn-in agreement with Beaver Bay, strengthening Franconia's previously indirect financial ties with the joint venture. The Birch Lake deposit contains 29 million metric tons (Mt) of resources grading 0.22% nickel, 0.69% copper, 1.13 grams per metric ton (g/t) palladium, and 0.57 g/t platinum. The average abundances of other precious metals are 2.8 g/t silver, 0.25 g/t gold, and 0.05 g/t rhodium. The resource estimate was based on assays from 16 drill holes and related wedges (Franconia Minerals Corporation, 2002b).

Franconia is a Canadian corporation that trades its stock on the OFEX, a market in London, United Kingdom, that specializes in the securities of newly formed companies. During the winter of 2001-02, Franconia drilled holes at two other PGE properties in the Duluth Complex—Cloquet Valley and Lillian. In May, the Alberta, Canada-based company also began drilling a layered intrusion at Sonju Lake (Franconia Minerals Corporation, 2002a). Franconia controls a total of 14 properties covering some 11,000 hectares (ha) within the complex. Franconia's exploration program is being partially funded by Impala Platinum Holdings Limited of South Africa (Implats), the second largest platinum producer in the world. By mid-2003, Implats had contributed $800,000 to the Franconia program. The State of Minnesota also was contributing some funds. The State has agreed to pay 40% of the direct costs of the first hole drilled on each of four selected targets in the complex (Franconia Minerals Corporation, 2003).

In October 2000, Teck Cominco American Inc. (a United States subsidiary of Teck Cominco Limited of Vancouver, British Columbia, Canada) formed a strategic alliance with Franconia and acquired a 7% interest in the Alberta corporation. Teck Cominco also is involved in the South Voisey's Bay nickel exploration project in Labrador. (More information about the Labrador project can be found under "Canada" in the "World Review" section of this chapter.)

Mesaba Project.—Teck Cominco American has been evaluating the Mesaba deposit, about 19 km south of Babbitt. AMAX Inc. and Bear Creek Mining Company conducted the initial analysis of the property—formerly known as the Babbitt deposit—during the 1970s. Extensive underground and surface drilling followed the initial analysis. In 2001, Teck Cominco negotiated option agreements with Longyear Mesaba Company and the State of Minnesota, which currently hold the mineral rights to the deposit. Teck Cominco estimates that it would cost $530 million to develop the very large, low-grade resource of copper and nickel. Cominco Engineering Services Ltd. (CESL) (a subsidiary of Teck Cominco) has developed a patented hydrometallurgical process for extracting copper and nickel from low-grade concentrates that may be applicable to some resources of the Duluth Complex. Teck Cominco has applied for a permit to extract 35,000 to 50,000 t of Mesaba material for bulk sampling. The bulk sample would be processed at Hoyt Lakes into 750 to 1,000 t of concentrate. The concentrate would then be shipped to the CESL demonstration plant in Vancouver, British Columbia, for further testing (Iron Range Resources and Rehabilitation Agency, 2002§). The CESL process has several advantages over traditional pyrometallurgical refining. Because the CESL process is hydrometallurgically based, the copper, nickel, and precious metals can be recovered without the production of sulfur dioxide (SO_2) gas. The closed loop process minimizes the production of effluents and can treat concentrates containing relatively high levels of arsenic and/or fluorine (Jones and Moore, 2002).

A 10-member advisory committee, that includes local citizens, has been formed to promote the development of a mine on the Mesaba property. Teck Cominco has proposed using part of the shuttered facilities and infrastructure of the iron ore mining complex at nearby Hoyt Lakes to process the copper-nickel ore. LTV Steel Mining Company, the defunct owner, was forced to close the huge beneficiation and agglomeration complex in January 2001 because of financial problems. The low-grade copper-nickel ore would be railed 25 km to Hoyt Lakes where it would be concentrated. A demonstration plant would be built onsite to evaluate the effectiveness of CESL's new extraction process and would be designed to produce a minimum of 10,000 metric tons per year (t/yr) of copper cathode and about 2,000 t/yr of nickel contained in a mixed nickel cobalt hydroxide. Zinc recovery is also possible. Teck Cominco still must secure financing, environmental permits, and community approval before any development can proceed (National Mining Association, 2003§). Teck Cominco applied to the State of Minnesota for a $20 million loan to help launch the project (Iron Range Resources and Rehabilitation Agency, 2002§). If construction were to begin in 2005, the demonstration plant could be operational by 2009. If everything goes well, construction of a full-scale plant could begin as early as 2007. The new metals producer would be called Mesaba Metals, LLC (University of Minnesota—Duluth, 2003). The full-scale Mesaba plant would have an output of 110,000 t/yr of copper cathode and 20,000 t/yr of nickel in the form of mixed hydroxide (Jones and Moore, 2002). The nickel output would be about one-sixth that of the full-scale Inco hydrometallurgical plant being designed for Argentia, Newfoundland, Canada.

Production

Primary Production.—The United States did not have any active nickel mines in 2002. All of the country's needs were met by imports or recycling. Glenbrook Nickel Co. decommissioned its mining and smelting complex near Riddle, OR, in 2000. The commissioning of the Loma de Niquel ferronickel operation in Venezuela in December 2000 and the expansion of existing capacity in Colombia, Indonesia, and New Caledonia have discouraged potential ferronickel producers from building facilities elsewhere in the Western United States.

In 2002, the State of Oregon recognized the outstanding reclamation work done at the Nickel Mountain Mine by Glenbrook and nominated the company for a special citation of excellence. Nickel Mountain was the last operating metal mine in Oregon. The site is 5 km west of Riddle in southern Douglas County. In 2003, the Mineral Land Regulation and Reclamation Program Office of the Oregon Department of Geology and Mineral Industries gave Glenbrook one of three mine reclamation awards, citing the company's dedication in restoring the Lower Ore Body side hill cut to a level far exceeding statutory requirements. Reclamation of the 26-ha (64-acre) hill cut had been underway since 1999. Five ponds connected by rock-lined channels were constructed to properly manage perennial water flow on the mountain. Invertebrates, amphibians, and waterfowl have colonized the pond system and renewed wetlands. Glenbrook is a subsidiary of Teck Cominco Limited (Oregon Dept. of Geology and Mineral Resources, 2003§).

Limited quantities of byproduct nickel were recovered at some copper and precious-metal refineries. Stillwater Mining Company has been mining PGE and gold since 1986 from the Stillwater Complex at Nye in Montana's Beartooth Mountains. The ore is associated with the 45-km-long J-M Reef. The company's two mills (Nye and East Boulder) together processed 1,250,000 t of ore and subgrade material in 2002, with a mill head grade of 17 g/t of palladium and platinum. About 80% of the ore came from the Stillwater Mine at the eastern end of the reef. The remaining 20% came from the new East Boulder Mine, which began production on January 1, 2002. Concentrates from the Nye and East Boulder mills were being trucked to the company's smelting and refining complex at Columbus, MT, where a filter cake containing approximately 60% palladium and platinum was being produced. In 2002, the refinery also produced byproduct nickel sulfate and shipped 639 t of nickel in solutions or crystals. Base-metal refiners in Canada and Finland were helping Stillwater market the nickel sulfate (Stillwater Mining Company, 2003a, p. 9-10; b, p. 14-15).

On November 20, Stillwater signed a definitive ownership agreement with MMC Norilsk Nickel, the largest producer of nickel and PGE in Russia. Under the agreement, Norimet (a wholly owned subsidiary of Norilsk Nickel) was to acquire a 51% interest in Stillwater and become the majority shareholder. Stillwater was to issue and hand over 45.5 million shares of Stillwater common stock in exchange for $100 million cash and 27.3 t (877,000 troy ounces) of palladium valued at the time at $241 million. Stillwater also agreed to purchase 31.1 t/yr (1 million ounces per year) of palladium from Norilsk Nickel. At yearend, the U.S. Federal Trade Commission was conducting an antitrust review of the proposed transaction—a requirement imposed by the Hart-Scott-Rodino Antitrust Improvements Act (Stillwater Mining Company, 2003b, p. 21-22).

Limited tonnages of primary nickel are recovered during the refining of some crude oils. Like vanadium, the nickel occurs in the crude oil as porphyrins or other organometallic compounds. The nickel and vanadium contents of crude oil are quite variable and reflect several factors, such as the density of the oil, the sulfur content of the oil, the field location, geologic occurrence, and geologic age. The nickel and vanadium are concentrated in (1) flexicoke and other petroleum refinery residues; (2) fly ash, ash sludge, slag, and boiler scale produced at oil-fired powerplants; and (3) spent petroleum refinery catalysts.

Secondary Production.—Inmetco continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. The facility was set up in 1978 to reclaim chromium and nickel wastes generated by the stainless steel industry. Because of subsequent improvements to the facility, Inmetco can accept a broad spectrum of other recyclable nickel- and/or chromium-bearing wastes, including filter cakes, plating solutions and sludges, catalysts, refractory brick, and spent batteries. Inmetco is the only facility in North America that can thermally recover cadmium from NiCd batteries. The RBRC program has been encouraging consumers to return their spent NiCd and NiMH batteries to commercial outlets where the batteries are stockpiled and eventually shipped to Ellwood City. Inmetco also reclaims large industrial cells that are used by railroads, electric utilities, the military, and telecommunication companies for backup power. An estimated 1,800 t of NiCd batteries was collected in the United States and Canada in 2002. Although the tonnage of nickel-based batteries being recycled has increased dramatically since 1996, a significant number still end up in landfills.

Spent catalysts are another U.S. source of nickel. Nickel is incorporated into the structure of some catalysts (such as nickel molybdate) and can be recovered when the spent catalyst is autoclaved and separated from its carrier. CS Metals of Louisiana, LLC recovered vanadium oxide and molybdenum oxide from spent catalysts at its reclamation facility on the Mississippi River at Convent, LA. The bulk of the catalysts came from oil refining and petrochemical operations. The $80 million facility, commissioned in October 2000, also produced a nickel-cobalt byproduct. The plant has the capacity to produce 2,300 t/yr of contained nickel in addition to 1,800 t/yr of vanadium pentoxide and 1,800 t/yr of molybdenum oxide (Ryan's Notes, 2002). CS Metals originally was a joint venture of Strategic Minerals Corporation (STRATCOR) (Danbury, CT) and CRI Metal Products, Inc. (Houston, TX). In late 2002, CRI bought out STRATCOR's 50% interest and became sole owner of the facility. CRI is a wholly owned member of the Royal Dutch/Shell Group of companies (Strategic Minerals Corporation, 2002).

Gulf Chemical and Metallurgical Corporation of Freeport, TX, also processes spent catalysts. The Freeport facility can treat nickel/molybdenum and cobalt/molybdenum hydrotreating catalysts with or without vanadium present. The principal products are oxides of molybdenum and vanadium, fused alumina, and a crude nickel-cobalt alloy byproduct. The nickel-cobalt alloy is produced in an electric furnace and sold to nickel refineries. Several of the metals recovered from the spent catalysts are used to manufacture fresh hydrotreating catalysts.

Consumption

In 2002, demand for primary nickel in the Western World was reported to be 1,032,000 t, up 6% from the 968,700 t (revised) of 2001. Demand was at an alltime high and broke the previous record of 1,024,000 t set in 2000 (International Nickel Study Group, 2003a, b). U.S. apparent consumption of primary nickel was 121,000 t, or about 12% of Western demand. U.S. industry consumed an additional 99,800 t of nickel in scrap. Within the United States, the share of primary nickel consumed in the production of stainless and alloy steels increased by 22% to 49% in 2002 from 40% in 2001. The large gain in market share was attributed largely to the startup of the new meltshop of North American Stainless (NAS) at Ghent, KY, on February 2. NAS is a wholly owned subsidiary of Acerinox, S.A. of Madrid, Spain—the third largest stainless steel producer in the world. In addition to Ghent, Acerinox has a 1.0-Mt/yr meltshop at its Campo de Gibraltar plant near Cadiz, Spain (Acerinox, S.A., 2003).

U.S. demand for most nonferrous alloys weakened because of the downturn in the general economy after September 11, 2001. Markets for copper-nickel alloys, nickel-base corrosion resistant alloys, and superalloys were especially hard hit. Demand for superalloys—key fabrication materials for jet engines—deteriorated sharply after September 11. U.S. airlines were forced to cancel orders for new civil transport because of the sharp drop in passengers carried and declining revenues.

The estimated value of apparent primary nickel consumption in the United States in 2002 was $823 million, up from $767 million in 2001, even though total apparent consumption dropped 6% from 129,000 t. The 7% increase in the value of consumption was because a 14% increase in the London Metal Exchange (LME) cash price more than offset the 12% decline in apparent primary consumption.

Stainless Steel and Low-Alloy Steels.—In 2002, the United States and world demand for nickel continued to be driven by the stainless steel industry. Stainless steel producers accounted for 46% of primary nickel demand in the United States and more than 60% of primary demand in the world. Production of raw stainless steel in Western countries has more than doubled in the past 15 years, growing to 17.99 Mt in 2001 from 8.21 Mt in 1986 (Inco Limited, 2002e, p. 1-8). Utilization of stainless steel melt capacity in the Western World has climbed to an estimated 85% in 2002 from 74% in 1996. Because of the high utilization rate, additional melt capacity will have to be brought onstream by 2005 to accommodate the projected growth in demand for stainless steel. There also has been a shift to increasingly larger meltshops. Prior to 2000, only two companies had meltshops with a capacity larger than 900,000 t—Acerinox, S.A. and Pohang Iron and Steel Co. Ltd. (POSCO). By yearend 2000, the number had risen to seven. The completion of expansion projects at Terni (Acciai Speciali Terni SpA's complex in Umbria, Italy), Tornio (AvestaPolarit's complex in Finland), Genk (Arcelor's complex in Belgium), and Kaohsiung (Yieh United Steel Corp.'s complex in Taiwan) added four more meltshops to the group. The commissioning of the greenfield meltshop at North American Stainless raised the number to seven. Baosteel also was building a 720,000 t meltshop at its No. 1 works in Shanghai, China. The new Chinese meltshop was scheduled to come onstream in 2004 (Inco Limited, 2002e, p. 9-13).

The world stainless steel industry continued to consolidate. AvestaPolarit Oyj Apb was formed in January 2001 by the merger of Avesta Sheffield AB with the stainless steel division of Outokumpu Oyj. Shortly afterwards, key producers in the continental part of the EU followed the path taken by AvestaPolarit. In December 2001, the Arcelor Group was created with the merger of Arbed S.A.

(Luxembourg), Aceralia Corporación Siderúrgica S.A. (Spain), and Usinor Sacilor S.A. (France). On January 9, 2002, Acerinox acquired a 46% interest in Columbus Stainless (Pty.) Ltd. and its huge complex at Middelburg (Mpumalanga), South Africa. In December 2001, three Japanese steel producers—Nippon Steel Corp., Nisshin Steel Co. Ltd., and Sumitomo Metal Industries Ltd.—announced that they had formed an alliance to reduce costs and improve capacity utilization.

Production of raw stainless steel and heat-resisting steel in the United States totaled 2.19 Mt in 2002, up 20% from 1.82 Mt in 2001. This tonnage was the second highest annual production recorded for the United States and was exceeded only by the record 2.20 Mt of 2000. Nickel-bearing grades accounted for 1.41 Mt, or 64% of the total stainless steel production for 2002 (American Iron and Steel Institute, 2003a, b).

Superalloys and Related Nickel-Base Alloys.—About 33% of the primary nickel consumed in the United States was used to make high-performance superalloys and related nickel-base alloys for the aerospace, electric power, and petrochemical industries. U.S. production of nickel-base alloys was down from that of 2001 because of a weakening of sales to manufacturers of jet aircraft engines. Sales to manufacturers of turbines for land-based powerplants remained at 2000-01 levels. The industrial gas turbine market has been in a period of rapid growth and was less affected by the recessionary events of 2001 and 2002 because of the long lead-times in powerplant construction.

Demand for superalloys is partially reflected in the production backlog and new orders for jet aircraft. Turbine blades, discs, and other critical parts of jet engines are fabricated from superalloys. The Boeing Company's backlog of orders for civil jet transports shrank dramatically after September 11, 2001, when airlines experienced financial difficulties and were forced to cancel orders (Donnelly, 2003).

Advanced Castings and Forgings Industry.—Nickel is used in a variety of brass, stainless steel, and superalloy castings. Nickel also is added to gray-iron castings to toughen the iron, promote graphitization, and improve machinability. The U.S. castings industry shipped an estimated 1.1 Mt of steel castings and 2.0 Mt of nonferrous castings in 2001. For comparison, iron castings shipments (gray, ductile, and malleable) were about 8.8 Mt.

Nickel-Based Batteries.—U.S. demand for nickel in rechargeable batteries may now exceed U.S. demand for several other important uses, such as copper-nickel alloys and coinage. U.S. imports of nickel-based batteries from China and Japan have been steadily growing.

Battery Manufacturing.—Texaco Ovonic Battery Systems LLC manufactures rechargeable NiMH batteries for electric, internal combustion engine (ICE)-hybrid electric, and fuel cell-battery hybrid vehicles.

The main plant is at Kettering, OH. Some key battery components, though, are produced in development facilities operated in Troy, MI, by Ovonic Battery Company, Inc.—one of Texaco Ovonic's two parents. Ovonic Battery is owned in turn by Energy Conversion Devices, Inc. (ECD) (91.4% equity). ECD is a leading developer of advanced energy technologies and is perhaps best known for its patents on the NiMH battery. Sanyo Electric Co. Ltd., Hitachi Maxell Ltd., and other ECD licensees produced more than a billion NiMH batteries in 2002.

Some of the other companies manufacturing nickel-based batteries in the United States were Eagle-Picher Technologies, LLC (Joplin, MO, and Colorado Springs, CO), Power Sion Inc. (Tampa, FL), Saft America, Inc. (Valdosta, GA), Sanyo Energy (U.S.A.) Corp. (San Diego, CA), and Yuasa America, Inc. (San Diego, CA).

Electric and Hybrid Electric Vehicles.—Sales of hybrid automobiles are forecast to grow in North America, increasing demand for nickel-based batteries. Since 1997, demand for hybrid automobiles has grown dramatically in Japan and North America, expanding opportunities for NiMH batteries. The NiMH battery is in competition with the valve-regulated lead-acid battery and the more expensive lithium-ion battery.

At the present time, only three hybrid passenger cars can be readily purchased in North America—the two-seat Honda Insight, the five-seat Honda Civic Hybrid, and the five-seat Toyota Prius. Major automobile manufacturers, however, are planning to offer many more models over the next 5 years (Thackray, 2002§). In January 2003, auto industry executives made several key announcements about the future of hybrid vehicles. The announcements were made in conjunction with the 2003 North American International Auto Show in Detroit, MI. The announcements were a strong endorsement of hybrid technology—a technology that significantly improves gasoline mileage by linking the power of the internal combustion engine to the power of the electric motor.

The recently introduced 2003 Civic Hybrid is equipped with a 50-liter (13.2-gallon) fuel tank, giving it a cruising range of more than 1,050 km (650 miles). This equates to about 46 miles per gallon in city traffic and 51 miles per gallon on the open highway. The 144-volt NiMH battery pack contains 120 cells, each with a potential of 1.2 volts. The battery pack and power control module are located together behind the back seat. A rear-shelf vent allows the cells to be warmed by ambient air from the cabin to help improve their cold-weather performance. When the gasoline engine is operating, the electric motor becomes a generator and automatically recharges the battery pack. The battery pack comes with an 8-year/129,000-km (80,000-mile) limited warranty (American Honda Motor Co., Inc., 2003§).

Ford Motor Company was planning to launch a hybrid version of its Escape sport utility vehicle (SUV) in December 2003. On January 8, 2003, Toyota Motors Sales, U.S.A. announced that it would begin marketing a hybrid version of its luxury SUV Lexus RX330 in late 2004. General Motors Corporation (GM) is expected to make its first foray into hybrids in 2004-05, by offering an electric powertrain option with its Saturn Vue SUV. GM also was planning to offer some form of hybrid electric power on four other popular, high-sales volume models by 2007 (Electric Vehicle Progress, 2003). The four models under consideration are the 2007 Chevrolet Malibu (a passenger car) and three pickup trucks—the 2005 Chevrolet Silverado, the 2005 GMC Sierra, and a new model to be introduced in 2006, the Chevrolet Equinox (Hakim, 2002a, b; 2003).

The Chrysler Group unit of DaimlerChrysler has been less optimistic about the future of hybrids and more cautious in its research and development programs, focusing its efforts instead on improving diesel technology. DaimlerChrysler engineers have taken a simpler and lower cost approach to hybrids than Honda and Toyota, designing vehicles with segregated powertrains. The gasoline engine drives the rear wheels, while the electric motor and battery pack power the front axle. Daimler-Chrysler is considering marketing a hybrid megapickup truck with special features that would appeal to the construction industry. The proposed hybrid would be equipped with a built-in field generator capable of supplying electrical power to large saws, drills, lathes, and other heavy-duty contractor tools (Thackray, 2002§).

About 39,000 hybrid vehicles are currently on U.S. highways. Even if only part of the announced plans materialize, the number of hybrid vehicles in North America could rise above 1,000,000 by 2007. Toyota has produced more than 100,000 Prius sedans since 1997 and is gearing up to manufacture 300,000 units per year. Continuing high prices for gasoline, concerns about possible disruptions of oil production in the Persian Gulf, and new restrictions on automobile emissions have helped to boost hybrid sales.

Some of the best opportunities for hybrid conversion may lie with vehicles that consume large amounts of fuel, such as city buses and full-size trucks. Bus manufacturer New Flyer of America, Inc. has supplied hybrid buses to at least three transit systems on the Pacific Coast—Orange County Transportation Authority (southern California), Tri-Met Transit (Portland, OR), and King County Metro Transit (Seattle, WA). The buses are powered by an advanced hybrid-electric powertrain system manufactured by the Allison Transmission Division of GM. The U.S. Army has awarded a contract to GM for the development of a prototype hybrid electric truck. The truck was to be equipped with a fuel cell capable of generating auxiliary power for surveillance and communications equipment. UQM Technologies Inc. is working on unmanned hybrid combat vehicles for both the U.S. Army and the U.S. Marine Corps. The UQM work is part of a much larger development project overseen by Carnegie Mellon University (Electric Vehicle Progress, 2002).

All of these activities are expected to spur demand for nickel metal foam, nickel oxide, and other nickel starting materials.

Stocks

On December 31, U.S. consumer stocks of primary nickel (cathode, pellets, briquettes, powder, etc.) totaled 3,290 t—21% less than the 4,190 t (revised) at yearend 2001. Stocks in LME warehouses, in contrast, grew irregularly during 2002 to 21,972 t. Monthly LME stocks peaked at 27,990 t on June 30. LME stocks have gone through two major cycles since 1990. LME stocks declined almost continuously between December 1998 and March 2001—starting at 65,964 t and bottoming out at 9,000 t. LME stocks at yearend 2000 and 1999 were 9,678 t and 46,962 t, respectively.

Data collected by the International Nickel Study Group indicated that, at yearend 2002, world nickel producers (excluding those in Austria, China, the former Yugoslavia, and the Ural area of Russia) had approximately 89,100 t of nickel in primary products in stock (International Nickel Study Group, 2003b). About 71% or 63,100 t of the producer material was Class I materials. Class I materials are refined products with a nickel content of 99% or greater (electrolytic cathode, pellets, briquettes, rondelles, powder, etc.). All stocks in LME warehouses are Class I. Class II materials include ferronickel, oxide sinter, and East Asian utility nickel—products with a nickel content less than 99%.

Prices

The January 2002 average cash price for 99.8% pure metal on the LME was $6,043 per metric ton ($2.741 per pound). The February average was $6,029 per ton ($2.735 per pound)—the low point for the year. The monthly average price rose during the spring and summer, eventually peaking in November at $7,314 per ton ($3.318 per pound). In December, the price dropped slightly to $7,193 per ton ($3.263 per pound).

In 2002, the last weekly price (for the week ending December 27) was $7,218 per ton ($3.274 per pound). The average annual price was $6,772 per ton ($3.072 per pound). The average price in 2002 was 14% greater than the 2001 average of $5,945 per ton ($2.696 per pound).

Foreign Trade

U.S. net import reliance as a percentage of apparent consumption was 48% in 2002—slightly higher than the 46% for 2001 because of decreased substitution of scrap for primary nickel by consumers. Imports accounted for almost 100% of primary supply. The United States imported 121,000 t of primary nickel in 2002, 11% less than the 136,000 t for 2001. The 2002 tonnage was the lowest since 1992. Class I materials accounted for 86% of total primary imports received. Canada, as usual, supplied most of the primary materials. The second largest source was Russia, recapturing the position from Norway. Norilsk Nickel has been an important source of nickel metal for the United States since the dissolution of the Soviet Union. Australia also moved ahead of Norway, with increased shipments from Bulong, Cawse, and Murrin Murrin—three new pressure-acid leach operations near Kalgoorlie. Almost all Norwegian nickel was produced from foreign matte processed at Falconbridge Limited’s refinery in Kristiansand.

On March 5, the U.S. Government took steps to slow the flow of foreign steel into the United States by temporarily raising tariffs on many finished steel products, including some forms of nickel-bearing stainless steel (Bush, 2002a, b). The higher tariffs were to remain in effect for 3 years. The tariff hikes were designed to give the beleaguered U.S. steel industry an opportunity to restructure, merge synergistic business units, consolidate, and continue with its long-term modernization program. Steel industry executives, labor union leaders, and their political allies claimed that a surge of low priced imports plus unfair trading practices by foreign countries were responsible for the latest round of U.S. steel company bankruptcies, job layoffs, and plant closures. In December 2001, domestic steel prices were at their lowest levels in 20 years. However, prices—especially for flat-rolled products—began to rise during the first quarter of 2002 (American Iron and Steel Institute, 2002; Office of the White House Press Secretary, 2002a, b; Pearlstein, 2002; Pearlstein and Allen, 2002; Sanger, 2002).

Several major consumers of steel—manufacturers of automobiles, farm machinery, appliances, etc.—opposed the administration's action. Steel users complained that the resulting higher prices for foreign steel would put their U.S. operations at risk, weaken the competitiveness of these U.S. operations in the global marketplace, and jeopardize far more American jobs than just those at risk in the U.S. steel industry. The trade action also could force some American companies to move manufacturing operations that consume large quantities of steel to overseas locations (Pearlstein and Allen, 2002; Sanger, 2002; Stevenson, 2002).

The decision by the U.S. Government to raise tariffs followed earlier findings by the U.S. Department of Commerce in 1999 and 2000 that several types of foreign steel were being sold in the United States at prices below production costs. In June 2001, the President formally asked the U.S. International Trade Commission (ITC) to determine whether the latest surge in steel imports had seriously damaged the U.S. steel industry. The ITC proceeded to conduct an injury investigation under section 201 of the Trade Act of 1974 (as amended). Section 201 is often referred to as "safeguard" or "escape clause" authority because it allows the President to take action without a finding of dumping or illegal subsidy. The investigators looked only at the effects of import growth and did not consider questions of dumping or illegal subsidy. On December 19, 2001, the ITC ruled that imports had indeed seriously injured the industry and recommended that the President issue import quotas and raise selected tariffs between 10% and 40%, depending on the type of steel (Bush, 2002b).

The new tariffs included increased duties on stainless steel bar, wire rod, and wire. The supplemental tariff schedules for the three products are the following: bar, 15% for the first year, 12% for the second year, and 9% for the third year; wire rod, 15% for the first year, 12% for the second year, and 9% for the third year; and wire, 8% for the first year, 7% for the second year, and 6% for the third year (Bush, 2002b, p. 10594). The new ad valorem duties are in addition to the "HTSUS Column 1," antidumping, and countervailing duties already in effect.

Stainless steel sheet and strip, which account for most U.S. imports of stainless steel products, were not part of the investigation and were not covered by the presidential order. The ITC also found that imports of semifinished stainless steel slabs had not injured U.S. slab producers. Other stainless steel products with negative findings were plate, pipe, wire cloth, and wire rope.

The temporary tariff changes took effect on March 20. The new tariff hikes are not uniform and are to be stepped back to zero during the next 3 years. The increases do not apply to steel produced in Canada or Mexico—U.S. partners in the North American Free Trade Agreement—and some developing countries. Semifinished carbon steel slabs will not be subject to the higher tariffs unless their volume of imports exceeds the levels of 2000. In contrast, carbon and alloy steel plate, including coated sheet and tin-plate, initially will have tariffs of 30%.

Since 1999, 33 steel companies have filed for bankruptcy. To date, the steel producers most at risk have been the old-line integrated steelworks, such as Bethlehem Steel Corporation, Geneva Steel LLC, LTV Steel Corporation, and Wheeling-Pittsburgh Steel Corporation—companies that use blast furnaces to produce steel from iron ore and coke. Several electric furnace operations, which primarily use scrap as feed, also have been hurt by the recent surge in steel imports. For example, Laclede Steel Co., an electric arc steelmaker in Alton, IL, ceased operations in August 2001. The import relief program is designed to help American stainless steel producers as well as the carbon steel sector. The domestic specialty steel industry, like the carbon steel sector, is struggling with problems of globalization, alleged dumping, and claimed excessive foreign government subsidization (Specialty Steel Industry of North America, 2002).

World Review

The world's largest nickel producer was Norilsk Nickel, followed by Inco. Other major producers were BHP Billiton Plc of the United Kingdom, Eramet Group of France, Falconbridge Limited of Canada, and WMC Limited of Australia. The six companies accounted for about 66% of world primary production in 2002. More than 30 medium- to small-companies supplied the remaining 34%. The nickel industry has become highly competitive as a result of recent corporate alliances and new developments in extractive metallurgy.

Anglo American plc of the United Kingdom restructured a portion of its holdings in the nickel industry during 2002. In September, Anglo American sold its 43.35% equity in Tati Nickel Mining Company (Pty.) Ltd. of Botswana to LionOre Mining International Ltd. Anglo American also was in the process of divesting its 26% interest in Anaconda Nickel Ltd. of Australia. At yearend, the mining giant had interests in the following four producers: BCL Ltd. of Botswana (23%), Bindura Nickel Corporation Ltd. of Zimbabwe (53.11%), Codemin S.A. of Brazil (90%), and Minera Loma de Niquel, of Venezuela (85.5%). Anglo American also was involved in the Barro Alto project (Brazil).

Australia.—In 2002, Australia was the third largest nickel-producing country in the world and was beginning to rival Canada. Most of the nickel properties under development are in the State of Western Australia. By yearend 2003, the nickel production capacity of Western Australia is projected to reach 200,000 t/yr. WMC was still the largest nickel producer in Western Australia recovering 106,423 t of nickel in sulfide concentrate in calendar year 2002, up from 104,591 t in 2001 (WMC Limited, 2003b).

Laterite Operations.—Three nickel laterite mining and processing operations have been commissioned in the Kambalda-Goldfields region since 1998—Bulong, Cawse, and Murrin Murrin. Together, the three initially should add about 60,000 t/yr of nickel to world production capacity. By 2001, however, only Cawse had approached design capacity. The other two continued to experience ramp-up problems.

Sulfide Operations.—WMC increased production at its three operations in Western Australia in response to strengthening nickel prices. WMC's smelter at Kalgoorlie produced 91,574 t of nickel in matte, down from 96,400 t in 2001 because of a fire at the sulfuric acid plant. WMC continued to evaluate its Yakabindie deposit 25 km south of Mount Keith. The Yakabindie deposit, acquired in early 2001, contains an estimated 289 Mt of resources averaging 0.58% nickel (WMC Limited, 2003a, p. 35).

In November 2001, LionOre (Nickel) Australia Ltd. commissioned the Emily Ann underground mine in the Lake Johnston area of Western Australia. (The company is an 80% subsidiary of LionOre Mining International Ltd.) The Emily Ann concentrates are being shipped to Thompson, Manitoba, Canada, for further processing by Inco Ltd. LionOre (Nickel) Australia has a 31% interest in the neighboring Maggie Hays massive sulfide deposit. The remaining 69% interest in Maggie Hays currently is held by QNI Pty. Ltd., a wholly owned subsidiary of BHP Billiton plc. On May 8, LionOre negotiated an option agreement to buy out QNI (Mining Journal, 2002c).

Botswana.—On September 30, LionOre Mining International Ltd. acquired the 43.35% equity position in Tati Nickel Mining Co. (Pty.) Ltd. held by Anglo American plc of the United Kingdom. The $75.9 million acquisition increased LionOre's equity in Tati Nickel from 41.65% to 85%. The Government of Botswana controls the remaining 15%. LionOre also was in the process of acquiring Anglo American's 23% equity position in Bamangwato Concessions Ltd. (BCL) (LionOre Mining International Ltd., 2002a§).

Tati Nickel was formed in 1988 to develop the Selkirk and Phoenix nickel-copper sulfide deposits in northeastern Botswana. The two mines are only 15 km apart and are located some 50 km east of Francistown. The Tati District has a long mining history and contains ancient copper workings, some of which date back to 600 A.D. The Selkirk underground mine was commissioned in 1989 and had been shipping about 60,000 t/yr of ore to BCL's smelter at Selebi-Phikwe. Tati was forced to close the Selkirk Mine in the first half of 2002 owing to depletion of reserves. The Phoenix Mine, an open pit operation with a dry magnetic separation plant, began production in 1995 and currently treats 1.7 million metric tons per year (Mt/yr) of ore, generating 120,000 t/yr of nickel concentrates for the BCL smelter (LionOre International Mining Ltd., 2002b§). BCL's smelter is about 350 km northeast of Gaborone, the capital of Botswana. The bulk of the concentrates for the smelter come from BCL's three neighboring cobalt-copper-nickel mines—Phikwe, Selebi, and Selebi North. In 2000, the smelter produced 62,000 t of matte containing 24,218 t of nickel, 20,977 t of copper, and 319 t of cobalt (Coakley, 2002).

Tati was in the process of commissioning a new concentrator at the Phoenix Mine. The new concentrator is a wet separation facility designed to generate 12,500 t of recoverable nickel and should be fully operational by yearend.

Brazil.—Companhia Vale do Rio Doce (CVRD) was considering becoming a nickel producer. CVRD is the largest diversified mining company in the Americas and the largest exporter of iron ore in the world (Centro Técnico-Científico da PUC-Rio, 1997§; Companhia Vale do Rio Doce, 2002§). On July 16, the mining giant announced that it had begun a prefeasibility study of the Vermelho nickel deposits in the Serra dos Carajás of northeastern Brazil (Reuters Limited, 2002c). The Vermelho (or Red) laterites were discovered in the 1970s during regional exploration of the Carajás area. According to company officials, the Vermelho deposits contain more than 220 Mt of lateritic ore averaging 1.23% nickel and 0.12% cobalt (Mining Journal, 2002b). The laterites are mineralogically similar to the limonitic laterites of Western Australia and, like the Australian ores, may be amenable to pressure acid leaching.

Brazil currently has three nickel producers as follow: CODEMIN S.A., Cia. Niquel Tocantins, and Mineração Serra da Fortaleza Ltda. CODEMIN and Tocantins mine laterites, while Fortaleza produces a matte for export from sulfide concentrates. Tocantins is the largest of the three and can produce up to 17,500 t/yr of electrolytic nickel and 300 t/yr of cobalt metal. CODEMIN is a ferronickel operation and can produce up to 6,500 t/yr of nickel in an alloy that averages 27% nickel. The capacity of the Fortaleza smelter is about 10,500 t/yr of nickel in matte. The matte is processed at the Harjavalta refinery in Finland.

The Vermelho nickel deposits, discovered in 1974, are 50 km southeast of the existing Carajás iron ore mining complex. Preliminary plans call for a $700 million metallurgical complex to be built adjacent to the proposed nickel mine, possibly a hydrometallurgical operation. The prefeasibility study is scheduled to be completed by October 2003 and should help project managers determine whether the lateritic ores should be converted into ferronickel, nickel oxide, or nickel cathode. If the prefeasibility study is positive, a bankable feasibility study could be completed as early as January 2005, with construction beginning shortly afterward. CVRD was hoping to commission the Vermelho plant in late 2007 or 2008. The plant would have a design capacity of 45,000 t of contained nickel, with the bulk of the nickel going to foreign consumers. Cobalt would be a byproduct, again for foreign consumption. The finished products would be trucked 75 km to the Carajás Railroad for transport to the Port of Ponta da Madeira.

Electric power for the nickel plant could come from the proposed Estreito hydroelectric power station to be built on the Tocantins River. The 1,087-megawatt (MW) hydroelectric project is a joint venture of CVRD (30%), Tractebel Egi South America Ltda. (30%), Alcoa Alumíno S.A. (19.08%), BHP Billiton Metals S.A. (16.48%), and Camargo Corrêa Energia Ltda. (4.44%) (Companhia Vale do Rio Doce, 2002). Power also could come from the proposed 1,087-MW Santa Isabel hydroelectric station in which CVRD has a 43.85% interest (Companhia Vale do Rio Doce, 2001).

Burma.—Mount Burgess Mining N.L. of Australia has been evaluating the Tagaung Taung laterite deposit 200 km north of Mandalay. The deposit reportedly contains 40 Mt of resources averaging 2.02% nickel (Roskill Information Services Ltd., 1993, p. 266; Metal Bulletin, 2003). Burmese and German geologists discovered the mountain top deposit in 1980 during a regional exploration survey of a remote and largely unpopulated part of Thabeikkyin Township. The original survey was funded by Germany's Bundesanstalt für Geowissenshaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources) and Burma's Technical Service Corporation. Geologists dug 19 prospecting shafts between 1980 and 1982 and drilled 104 bore holes between 1983 and 1986. Between 1985 and 1986, exploration crews dug 13 shafts to collect bulk samples.

Burundi.—On April 2, Argosy Minerals Inc. announced that it would resume its feasibility study of the Musongati lateritic nickel deposits in east-central Burundi. Since gaining independence in 1961, Burundi has been plagued by tension between the dominant Tutsi minority and the Hutu majority. The present transitional government is based on a sharing of power between the two ethnic groups. Argosy was forced to suspend work on the East African project in April 2000 because of security concerns for the company's onsite personnel. Political changes in Burundi since November 2001 and the deployment of South African peacekeepers have lessened security concerns in recent months (Reuters Limited, 2002b; BBC News, 2002§).

The Musongati project is being managed by Andover Resources NL (a wholly owned Australian subsidiary of Argosy). On March 11, 1999, the Burundi National Assembly ratified a mining convention between Andover and the Government of Burundi. The convention addresses a variety of mining issues, including mineral rights, royalties, taxation, and a work program (Argosy Minerals Inc., 2002§).

The nickel-cobalt-copper enrichment at Musongati was formed by the prolonged weathering of a flat-lying, layered intrusion of gabbro, norite, and other mafic-ultramafic rocks. Subsequent erosion has removed part of the mineralized zone and created three adjacent plateaus—Geyuka, Rubara, and Buhinda. The mineralized area covers about 16 km^2. Dry resources, at a cutoff grade of 0.8% nickel, are as follows: Buhinda, 72.5 Mt grading 1.56% nickel, 0.12% cobalt, and 0.30% copper; Rubara, 50.0 Mt grading 1.23% nickel, 0.054% cobalt, and 0.038% copper; and Geyuka, 62.2 Mt grading 1.09% nickel, 0.051% cobalt, and 0.137% copper. Total resources amount to 185 Mt at an average grade of 1.31% nickel, 0.08% cobalt, and 0.17% copper (Mining Journal, 1981; Derkmann and Jung, 1986; DeBlond, 1994; DeBlond and Tack, 1999; Argosy Minerals Inc., 2002§).

Most of the work to date has focused on the Buhinda plateau, where a 5- to 30-meter (m)-thick layer of limonitic laterite overlies a 5- to 25-m-thick layer of saprolite. As with most laterites, the saprolite has higher magnesium and lower iron values than the limonitic layer. At Buhinda, the nickel grade tends to increase slightly with depth into the saprolite and averages about 1.17% in the limonitic layer.

The Mukanda-Buhoro-Musongati complex of layered intrusions is part of a 350-km-long metallogenic belt that extends from Kabanga and Kasese in northwestern Tanzania south to Mibango and Lubalisi on the east side of Lake Tanganyika. The Musongati deposit was discovered in 1972 by an exploration team working for the United Nations Development Programme. Since 1972, there have been three phases of diamond core drilling, a bulk sampling program, and five metallurgical studies. Part of this work was funded by the World Bank. RTZ Corp. (the predecessor of Rio Tinto Plc) was actively exploring for nickel in the belt in 1993 but was forced to suspend operations indefinitely due to civil unrest.

Argosy has begun reevaluating geologic and geophysical data collected in the 1970s and 1980s. Company geologists are in the process of relogging core held in storage from drilling programs conducted in 1973-74 and 1983-84. The drill core information indicates that the Musongati deposits may contain commercial quantities of PGEs in addition to the nickel, cobalt, and copper. Some of the deeper drill holes have revealed that the laterites are underlain by a variety of ultramafic rocks, including pyroxenites, peridotites, and dunites—promising host rocks for PGE mineralization. At least eight other layered mafic-ultramafic intrusive complexes have been identified in the Kabanga-Musongati-Mibango belt. Argosy has concessions to explore laterites associated with two of the eight—Nyabikere and Waga (Argosy Minerals Inc., 2002; Duchesne and others, 2002; Mining Journal, 2002a).

Cameroon.—On August 1, the Government of Cameroon granted Geovic Cameroon S.A. exclusive rights to develop a cobalt-nickel deposit near Zoulabot, East Province. The deposit is about 29 km east of Lomie and on the edge of the Dja World Heritage Reserve. Geovic Ltd. of Grand Junction, CO, has a 60.5% equity position in the Cameroonian company. The remaining 39.5% is controlled by the Government of Cameroon and other stakeholders. The Geovic affiliate believes that it has discovered the largest primary cobalt deposit in the world. The company has been actively exploring the lateritized serpentinite deposit since its discovery in 1995.

The mining permit runs for 25 years and allows the company to produce a cobalt-nickel sulfide intermediate product for export. Exploration drilling and trenching indicate a resource in excess of 225 Mt, grading about 0.3% cobalt and 0.6% nickel (Geovic, Ltd., 2002). Six areas have been identified for future mining—(from north to south) Rapodjombo, Nkamouna, North Mang, South Mang, Messea, and Kondong. The mine would be an open pit operation. Nkamouna, the first deposit proposed for mining, has a 7-m-thick ore zone, starting, on the average, at a depth of 8 m below the surface. If the feasibility study is positive, mining could begin as early as 2005 (Sherborne, 2002). The cobalt and nickel would be extracted by heap leaching. The first phase of the two-part bankable feasibility study is being financed in part by the U.S. Trade and Development Agency (U.S. Embassy, Yaounde, Cameroon, 2002; U.S. Trade and Development Agency, 2002§).

Canada.—Key events of 2002 are summarized in the nickel chapter of the Canadian Minerals Yearbook (Bill McCutcheon, Natural Resources Canada, written commun. and unpub. data, 2003).

Newfoundland and Labrador.—All the stakeholders in the Voisey's Bay deposit of northeastern Labrador finally reached agreement on development. The last obstacles were removed in late June. After 6 years of negotiations, Inco Limited and the Provincial Government of Newfoundland and Labrador finally agreed on how to develop the huge nickel-copper-cobalt deposit (Inco Limited, 2002b; McNish and Cox, 2002). The deposit, found in 1993, is the most important base-metal discovery in Canada in more than 35 years. Inco acquired the Voisey's Bay deposit from Diamond Fields Resources Inc. through a complicated series of financial and stock transactions between 1994 and 1996. The acquisition cost Inco $3.7 billion. The Toronto, Ontario-based company is planning to invest an additional $1.9 billion during the 30-year life of the project. The project is expected to have an impact of $7 billion on the Provincial gross domestic product during the 30-year period.

On June 11, the Newfoundland Government and Inco issued a joint statement of principles, allowing development to begin immediately. The final, legally binding agreements were signed on September 30. On June 20, the Provincial House of Assembly voted in favor of the development agreements. The last hurdles to development were removed on June 25 when the Labrador Inuit

Association and the Innu Nation ratified separate impacts/benefits agreements with Inco (Reuters Limited, 2002a). The mining and metallurgical project is expected to generate billions of dollars and about 2,400 jobs in one of Canada's poorer provinces (Bill, 2002a, b; Government of Newfoundland and Labrador, 2002a-c).

Under the terms of its agreements with the Provincial Government, Inco will construct and operate:

1. an integrated mine and mill/concentrator at the Voisey's Bay site (at an estimated cost of $470 million);
2. a hydrometallurgical demonstration plant at Argentia on the Avalon Peninsula of Newfoundland (at an estimated cost of $85 million); and, if the demonstration technology proves economically viable,
3. a hydrometallurgical nickel-copper-cobalt concentrate processing plant at Argentia (at an estimated cost of $530 million). The plant would be capable of producing 50,000 t/yr of nickel and employ about 400 people.

If the new hydrometallurgical process fails to be economically or technically feasible, Inco would build a more conventional smelting and/or refining complex in its place. The company also has agreed to develop and support a $13 million innovation and research center at St. John's in cooperation with Memorial University of Newfoundland. The new center would focus its educational and research efforts on mineral exploration, mining, and metallurgy (Inco Limited, 2002b).

Inco was planning to spend a minimum of $36 million between June 11, 2002, and March 31, 2003, at Voisey's Bay, Argentia, and St. John's. Construction of the mine and mill/concentrator was scheduled to begin in 2003. The mill/concentrator was being designed to process 6,000 metric tons per day of ore and could be producing concentrate as early as 2006. Inco was hoping to commission the Argentia demonstration plant in 2006 and complete its feasibility studies at the plant by 2008. Construction of a commercial hydrometallurgical processing plant at Argentia would require an additional 3 years, with a projected commissioning date of 2011. The company has promised to process imported nickel concentrate at Argentia after the proposed plant is commissioned. The imported material would compensate the Province for concentrate shipped between 2003 and 2011 to Inco's smelters at Sudbury, Ontario, and Thompson, Manitoba (Government of Newfoundland and Labrador, 2002c; Hasselback, 2002§).

Ontario.—Several exploration and development projects were underway in the Sudbury Igneous Complex of Ontario. Investigators published several new investigations and geologic interpretations of the complex's associated copper-nickel deposits.

In 1883, a crew constructing the Canadian Pacific Railway discovered the first of numerous magmatic sulfide deposits located around the periphery of the Sudbury basin in east-central Ontario (Giblin, 1984). Since then, more than 10 Mt of nickel have been recovered from the mining district (Lesher and Thurston, 2002). The Sudbury District is also an important source of copper, cobalt, and PGE. The copper content of the typical Sudbury ore is approximately equal to the nickel content. In 2001, the Sudbury operations of Falconbridge Limited processed 1.95 Mt of local ores with an average grade of 1.61% nickel and 1.35% copper (Falconbridge Limited, 2002, p. 20). Inco Limited, Sudbury's other principal nickel producer, had equivalent ore grades of 1.57% nickel and 1.68% copper that year (Inco Limited, 2002a, p. 19).

At least 10 copper-nickel deposits have been discovered along the margins of the Sudbury basin since 1990. Three recent discoveries—at Kelly Lake, Nickel Rim South, and Totten—have spurred the expansion of exploration activities (Falconbridge Limited, 2002§; Inco Limited, 2000a§, b§).

In November, the Society of Economic Geologists published a special issue devoted to the mineral deposits of the Sudbury basin. This special issue supplements and updates four earlier special volumes and numerous other landmark publications dealing with the igneous complex. Many aspects of the complex's geologic history are still being debated despite more than a century of fieldwork and laboratory studies. The most recent evidence continues to support the theory that the Sudbury structure is an impact crater created when a meteorite struck the Canadian Precambrian Shield ~1.85 billion years ago (Therriault, Fowler, and Grieve, 2002).

The bulk of the sulfide ores are found intermittently along the base of the Sudbury Igneous Complex as complex mixtures of sulfide assemblages, xenoliths, and impact breccias. The principal sulfide minerals, in order of decreasing abundance, are pyrrhotite (Fe_{1-x} S), pentlandite [$(Fe,Ni)_9S_8$], chalcopyrite ($CuFeS_2$), pyrite (FeS_2), and bornite (Cu_5FeS_4) (Beswick, 2002; Magyarosi, Watkinson, and Jones, 2002).

Several papers in the special issue focus on the long, radial offset dikes which extend outward from the Sudbury structure into the much older Archaean and Paleoproterozoic Huronian metasedimentary rocks (2.5 billion to 2.2 billion years ago). Radiometric dating of the dike rocks indicates that they were formed about 1.8 billion years ago and are apparently related to the melt generation processes triggered by the impact. At least nine major offset dikes have been mapped. The Foy offset dike is the largest of the dikes radiating outward from the Sudbury Igneous Complex. The dike extends into the country rock for at least 30 km. Sulfides occur within the dike primarily as disseminated, blebby masses—usually as inclusions within quartz diorite (Tuchscherer and Spray, 2002). A second dike, the Whistle-Parum dike—is on the northeast perimeter of the basin, northwest of Lake Wanapitei. The 12-km-long radial dike and associated embayment are comprised of numerous rock types, including mafic sulfide-bearing breccia and inclusion-bearing quartz diorite (Murphy and Spray, 2002). A third dike, the Worthington dike, extends from the southwest margin of the igneous complex for about 15 km. The dike consists of a core of quartz diorite containing inclusions of amphibolite and semimassive to massive sulfide assemblages. In some places, the dike is 50 to 80 m in width (Lightfoot and Farrow, 2002).

The special issue also deals with the metallogenesis and geology of several much older (2.5 billion years ago) mafic intrusive complexes that formed in the Sudbury area long before the impact event. Two of these complexes—the East Bull Lake intrusion and the River Valley intrusion—are current exploration targets for PGE and could be sources of byproduct nickel (James, Easton, Peck, and Hrominchuk, 2002). (More information can be found in the nickel chapter of the 2000 Minerals Yearbook.) Some investigators have suggested that similar mafic intrusives may have been present at Sudbury when the meteorite struck and served as proto-ores for the nickel-copper-PGE mineralization of the Sudbury Igneous Complex.

Indonesia.—In 1999, the Indonesian Parliament passed the Forest Law, which took effect on January 1, 2001. The Forest Law prohibits mineral exploration and mining in protected forests that account for almost 40% of the land mass of Indonesia. This law has discouraged foreign investors from proceeding with the development of the Weda Bay nickel deposits on Halmahera Island. Because of the Forest Law and concerns of investors about a perceived decline in political stability, investment in the mining sector has declined significantly since 1998.

New Caledonia.—On December 5, Inco Limited announced that it was slowing key engineering and construction work on its Goro Project in the French Overseas Territory of New Caledonia (Platts Metals Week, 2002; Hand and Goudie, 2002§). Inco's management, concerned about rising estimates of Goro's capital costs, has begun a comprehensive review of the entire nickel-cobalt project. In September, Inco officials became wary when updated cost data and trend information from the company's contractors indicated that the projected capital cost of Goro had increased by at least 15%—rising to $1.67 billion from $1.45 billion. Inco has spent about $350 million on the project to date and has signed contracts committing an additional $300 million to $350 million for equipment and services. Inco was hoping to complete the comprehensive review by mid-2003 (Inco Limited, 2002c, d).

Inco was prepared to slow the construction schedule so that any design changes needed to ensure the economic viability of Goro could be incorporated at an early stage. The cost estimate increases were attributed to unforeseen geotechnical problems and evolving design requirements based on feedback from onsite pilot-plant work. The mining and hydrometallurgical processing complex had been scheduled to begin production in late 2004.

According to company officials, Goro has 54 Mt of proven and probable reserves, making the ore body one of the larger undeveloped laterite deposits in the world. The lateritic ore averages 1.53% nickel and 0.12% cobalt. Additional resources are expected to extend the life of the mine far beyond its planned 20 years. The mining and processing complex would produce 55,000 t/yr of nickel in nickel oxide and 4,500 t/yr of cobalt in cobalt carbonate. The project is a joint venture of Inco (85% equity) and Bureau de Recherches Géologiques et Minières (BRGM) (a French Government agency) (15%). A Japanese consortium led by Sumitomo Metal Mining Co., Ltd., has been negotiating to acquire a 25% interest in Goro. BRGM was considering selling its 15% share to Inco (Compagnie des Mines de Xéré and others, 2002).

Philippines.—On August 22, JGC Corporation of Yokohama, Japan, announced that it had won a lump-sum, turn-key contract to construct a nickel extraction complex at the Rio Tuba Mine on Palawan Island in the Philippines (McCulloch, 2002; JGC Corporation, 2002§). The ore processing plant—a hydrometallurgical facility—will be built adjacent to the existing open pit operated by Rio Tuba Nickel Mining Corporation (RTN). Feed for the new plant will come from a 16-Mt stockpile of low-grade lateritic oxide ore accumulated during 20 years of mining. The stockpiled ore reportedly averages 1.26% nickel. High pressure acid leach (HPAL) technology will be used to produce an intermediate nickel-cobalt sulfide feedstock for Sumitomo Metal Mining Co., Ltd. of Japan. Sumitomo produces electrolytic nickel and electrolytic cobalt at its Niihama smelting and refining complex in Ehime Prefecture, Japan (Sumitomo Metal Mining Co., Ltd., 2001, p. 11-12).

The complex would include a hydrogen sulfide plant, a limestone quarry, two tailings dams, a 9.9-MW coal-fired powerplant, and new port facilities (Philippine Society of Mining Engineers, 2002§). The operation is being designed to produce 10,000 t/yr of nickel plus 750 t/yr of cobalt in mixed sulfides. Construction is scheduled to be completed by late 2004 (JGC Corporation, 2002§).

The HPAL project is being funded and managed by the Coral Bay Nickel Corporation of the Philippines, a joint-venture company incorporated on July 1. Equity in the new joint venture is divided among Sumitomo (54%), Mitsui & Co., Ltd. (18%), Nissho Iwai Corp (18%), and RTN (10%). Coral Bay Nickel is headquartered in Bataraza, a Palawan municipality near the mine (Mining Journal, 2002d; Mitsui & Co., Ltd., 2002§).

On July 10, the Philippine Department of Environment and Natural Resources issued the environmental compliance certificate (ECC) needed to build and operate the $175 million complex. The project was also approved by the Palawan Council for Sustainable Development. The ECC was issued after lengthy and somewhat controversial hearings. The project had been opposed by several nongovernmental organizations, which expressed concerns about the handling and disposal of some 270,000 t/yr of sulfuric acid. Potential emissions of hydrogen sulfide were another concern. Palawan is home to many diverse species of flora and fauna and has been declared a biosphere reserve by the United Nations. Two spectacular natural attractions—the Puerto Princesa Subterranean Park and the Tubbataha Reef—are of particular concern (Palawan Times, 2002§; Tesorio, 2002§; Ticke and Sy-siong, 2002§).

Russia.—JSC MMC Norilsk Nickel announced long-range plans to increase nickel production capacity by 10%. On March 18, 2003, the board of directors of Norilsk Nickel approved a modernization plan designed to increase the company's nickel production capacity by 10%. Under the plan, nickel production capacity would be increased to 240,000 t/yr of nickel from the current level of 218,000 t/yr. Production of PGE would remain at approximately the current undisclosed level. Copper production, however, would drop to about 420,000 t/yr from 454,000 t in 2002 because of a switch to a different type of ore (Mining Journal, 2003; JSC MMC Norilsk Nickel, 2003a§, b§).

Modernization is expected to cost between $3.6 billion and $5.3 billion. The project is scheduled to be completed by 2015 and would be paid for from internally generated funds. Norilsk Nickel currently derives about 45% of its sales revenue from PGE, 33% from nickel, 14% from copper, and 8% from other sources. In 2001, Norilsk Nickel recorded a net profit of $469 million on revenues of $4,378 million (Prokhorov, 2002).

Norilsk Nickel has two main mining divisions—the Polar Division located on the Taimyr Peninsula of north-central Siberia and the Kola Mining and Metallurgical Company on the Kola Peninsula. Production operations would be upgraded in both divisions. The Polar Division would mine about 14 Mt/yr of ore, up slightly from 13.6 Mt/yr. Approximately 7.6 Mt/yr, or 54% of the total, would be high-grade ore. The amount of cuprous ore mined would be doubled to 5.0 Mt/yr, or 36% of the total, while production of disseminated ores would drop to about 1.4 Mt/yr, or 10% of the total. The Taimyr ores would yield about 200,000 t/yr of nickel and 400,000 t/yr of copper. About 6.0 Mt/yr of ore would be mined on the Kola Peninsula, down slightly from the current 6.4 Mt/yr. The Kola division, which incorporates the Pechenganickel and Severonickel Combines, would produce about 40,000 t/yr of nickel and 20,000 t/yr of copper.

Norilsk Nickel was planning to spend at least $125 million per year for the next 7 years to improve its Taimyr mining operations. The money would be used primarily to expand operations at the Oktyabrsky and Taimyrsky mines and to develop the Skalistaya deposit. Production from the Skalistaya Mine would help offset declining production at other mines in the Talnakh area that have limited reserves. Two open pit mines were developed at Norilsk during the 1940s. One of these mines, Medvezhiy Ruchey, is still operational. Additional reserves were discovered at Talnakh, 25 km northeast of Norilsk, during the 1960s (Bond and Levine, 2001).

Renovation of outdated beneficiation operations has been a major goal of the company since its partial privatization in 1997. Upgrading the Talnakh concentrating mill, which opened in 1981, could cost as much as $160 million. The mill produces three types of concentrates—nickel-rich pentlandite, copper-rich chalcopyrite, and nickel-bearing pyrrhotite.

Development of the Severny-Gluboky deposit on the Kola Peninsula and related improvements would cost an additional $25 million per year. The Tsentralny Mine is currently the largest nickel mine on the Kola Peninsula. The mine consists of two open pits and has been in production since 1956. Ore reserves at the Tsentralny Mine, however, are being depleted rapidly (RAO Norilsk Nickel, 2000).

Some $400 million would be spent between 2003 and 2008 modernizing sulfide flotation equipment, smelters, refineries, and related facilities. The sinter plant at Norilsk, which dates from the 1940s, and the smelting shop of the adjoining nickel plant would be permanently closed by 2007. New smelting facilities would be constructed at the Norilsk copper plant and the Nadezhda metallurgical plant (15 km west of Norilsk). The Nadezhda plant, a large smelter built with the assistance of Outokumpu Oyj, produces converter matte, anode copper, and other intermediate products (Bond and Levine, 2001). Company officials are hoping that the adoption of advanced high-grade matte leaching technology at Nadezhda will enable the complete closure of the Norilsk nickel plant and reduce the Polar Division's electricity costs at the refining stage by as much as 25%. Natural gas from the newly developed Peliatka gasfield will help to reduce energy costs even further. A matte-leaching pilot plant for Nadezhda would cost about $12 million. Adoption of the leaching technology at Nadezhda would cost an estimated $600 million. Elemental sulfur production facilities would be installed at the upgraded copper and Nadezhda smelters, sharply reducing SO_2 emissions. The new sulfur facilities would capture essentially all of the solid pollutants that now enter the atmosphere and would reduce SO_2 emissions on the Taimyr Peninsula by 70% from current levels. The construction of similar facilities at Pechenganickel could reduce SO_2 emissions on the Kola Peninsula by more than 90% by mid-2006. Grants and credits from the Government of Norway and the Nordic Investment Bank are in place to help pay for the Kola emissions reduction program (JSC MMC Norilsk Nickel, 2003b§).

In March 2003, Norilsk Nickel released 18,000 t of nickel from its 60,000 t stockpile. On April 8, the company announced that it was releasing an additional 18,000 t, lowering the stockpile to 24,000 t. The 60,000 t stockpile had been used as collateral to obtain a $200 million secured loan arranged by Credit Suisse First Boston International, ING Bank N.V., Standard Bank London Limited, and Natexis Banques Populaires in May 2002 (JSC MMC Norilsk Nickel, 2003c§).

In a second recent financial transaction, Norilsk Nickel agreed to invest $341 million in Stillwater in exchange for a 51% majority interest in Stillwater. Stillwater is the only U.S. producer of palladium and platinum and is the largest producer of primary PGM outside of South Africa and Russia.

Stillwater would transfer 45.5 million shares of newly issued common stock to Norimet, a wholly owned subsidiary of Norilsk, in exchange for $100 million cash and 27.3 t (877,000 ounces) of palladium. Stillwater's stockholders have not yet approved the Norilsk Nickel transaction (Stillwater Mining Company, 2003b, p. 68-70; JSC MMC Norilsk Nickel, 2002§). Stillwater has PGM mining operations on the J-M Reef in Montana near Nye and Big Timber. In 2002, Stillwater recovered 639 t (1,408,000 pounds) of byproduct nickel in solutions and crystals at its Columbus refinery (Stillwater Mining Co., 2003a, p. 9-10).

Spain.—On December 10, Rio Narcea Gold Mines, Ltd. announced that it had successfully arranged financing for its Aguablanca mining project in southwestern Spain. The proposed open pit mine was being designed to produce 9,100 t/yr of nickel, 6,800 t/yr of copper, and 780 kilograms per year of PGE—all in sulfide concentrates. Construction of the mine will cost an estimated $64 million. Rio Narcea has been producing gold at its 100%-owned El Valle and Carlés mines in Asturias since 1998 (Rio Narcea Gold Mines, Ltd., 2002b§).

Investec Bank (UK) Ltd. and Macquarie Bank Ltd. have agreed to a $45 million loan that would extend for 6 years. The package would include an additional convertible loan of $5 million, a cost overrun provision of $5 million, plus nickel and copper hedging that would cover the equivalent of 50% of nickel production. The commodity hedge program should provide adequate protection for the two banks against a steep drop in nickel prices while enabling Rio Narcea to benefit from upside gains. Barclays Bank, S.A.E. would provide an additional $6 million credit to cover value-added taxes as well as legal and closing fees. At yearend 2002, Rio Narcea had $10 million in cash on hand and was expecting strong cash flows from its gold operations in 2003 (Rio Narcea Gold Mines, Ltd., 2002b§).

The Aguablanca Mine would have a life of at least 10.5 years based on a bankable feasibility study completed in July. The feasibility study was prepared by Metallurgical Design and Management (Pty.) Ltd. of South Africa. Metallurgical test work on representative core and bulk samples was conducted by Mintek Laboratories of South Africa. The Aguablanca property was previously owned by Rio Tinto Minera S.A. and Presur S.A. The property reportedly has 18.5 Mt of resources averaging 0.67% nickel, 0.49% copper, 0.61 g/t PGE, and 0.15 g/t gold. In addition, there is 9.9 Mt of inferred resources having similar grades. The resource estimate is based on 32,000 m of drilling conducted by Rio Tinto and Presur between 1993 and 1996 (Rio Narcea Gold Mines, Ltd., 2002, p. 2). The nickel sulfide ore would be processed onsite in a conventional flotation plant designed to treat 1.5 Mt/yr of ore. The property is close to a major highway that connects to the ports of Seville and Huelva (Rio Narcea Gold Mines, Ltd., 2002a§, c§).

On January 20, 2003, Rio Narcea announced that it had signed a long-term offtake agreement with Glencore International AG. Glencore will purchase 100% of the nickel sulfide concentrate produced at Aguablanca until the year 2010. The mine is scheduled to be commissioned in 2004. Specific terms of the agreement were not disclosed to protect confidential business information (Rio Narcea Gold Mines, Ltd., 2003b§).

Rio Narcea is actively evaluating several other promising nickel properties in the Serra de Ossa (Portugal)-Sierra Morena (Spain) region besides Aguablanca. The company has identified at least 10 mineralized gabbro intrusives along the 150-km-long Olivensa-Monesterio antiform of Spain's Badajoz Province.

Rio Narcea has begun exploring for nickel in southern Portugal as well as in Spain. Rio Narcea applied to the Portugese mining authorities for a license to explore two key districts in the Alentejo region bordering Badajoz Province. The license would cover a 927-km^2 block in the Campo Maior area and a 993-km^2 block in the Beja area. The Beja area includes a large ophiolite belt in contact with a mafic-ultramafic complex of olivine gabbros, anorthosites, norites, and troctolites. Outcrops of gossanous troctolite near Elvas in the Campo Maior area assayed up to 0.8% nickel and 0.5% copper. The village of Elvas is 10 km west of the Spanish border and about 135 km northwest of Aguablanca (Rio Narcea Gold Mines, Ltd., 2003a§).

Outlook

No principal nickel producer is expected to be operating in the United States before 2015. The Groupo Mexico and Stillwater will continue to recover limited amounts of byproduct nickel from their precious metals and base metals refining operations in the Western States. Larger amounts of byproduct nickel also could be generated in Minnesota if Teck Cominco decides to proceed with its Mesaba PGE Project in the Duluth Gabbro. Increased byproduct nickel production from North American PGE operations could materialize if current forecasts for fuel cell-battery hybrid vehicles come true.

U.S. nickel consumers will continue to be dependent on foreign sources for at least two decades. The ongoing expansion of nickel laterite mining projects in Australia, Cuba, Indonesia, New Caledonia, and the Philippines will help meet the growing demand for nickel worldwide. Laterite projects also are under consideration in Brazil, Cote d'Ivoire, and Guatemala. Contractors for Inco have begun constructing the company's state-of-the-art mill and concentrator at Voisey's Bay, Labrador. The sulfide concentrate from Voisey's Bay also will help meet the near-term growth in demand projected for nickel.

Nickel consumption in the United States is expected to grow at least 3% per year as stainless steel is increasingly substituted for other materials. Substitution will cut maintenance costs and improve safety in a number of situations. One example is the adoption of corrosion-resistant stainless steel rebar for highway and bridge projects. Use of stainless steel in new home and building construction is expected to grow because of its resistance to fire and high winds. This could be important in areas like southern California that are prone to wildfires. Growth in nickel demand by the domestic plating industry is expected to be minimal. A number of small U.S. plating operations reportedly have closed in recent years. A large part of the world's plating needs are now being met by China and other countries where labor costs are much lower than in the United States. The aerospace industry will continue to use significant amounts of nickel, despite the short-term lull in aircraft and jet engine production since September 2001. A number of new nickel alloys are currently being developed specifically for the aerospace industry where extreme temperatures are a major problem. Demand for nickel in electronics, stationary power sources, and grid-dependent electrical equipment is growing. Advanced nickel-based batteries are being developed for a wide range of ICE-electric hybrid vehicles—automobiles, SUVs, trucks, armored vehicles, and even railroad locomotives. Storage batteries will also be needed to capture the energy generated by many of the fuel cells now being designed. The capturing of the energy by regenerative braking is becoming an important factor in the design of new automobiles and trucks that continually have to operate in heavily congested metropolitan areas.

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TABLE 1

SALIENT NICKEL STATISTICS[1]

(Metric tons of contained nickel and dollars per matric ton unless otherwise specified)

	1998	1999	2000	2001	2002
United States:					
Mine production	--	--	--	--	--
Plant production	4,290	--	--	--	--
Secondary recovery from purchased scrap:					
From ferrous scrap	52,700	58,600	71,700 r	89,600 r	90,700
From nonferrous scrap	10,400	12,400	12,200	11,200 r	9,090
Shipments of purchased scrap[2]	89,700	93,000	123,000	141,000	130,000
Exports:					
Primary	8,440	7,440	8,150	8,450	6,520
Secondary	35,100	31,400	49,900	48,600	39,400
Imports for consumption:					
Ore	1,420	--	--	--	--
Primary	148,000	139,000	156,000	136,000	121,000
Secondary	8,500	9,480	10,700	8,760	9,110
Consumption:					
Reported:					
Primary	116,000	116,000	115,000	98,800	87,300
Secondary, purchased scrap[3]	63,100	71,000	84,000	101,000	99,800
Total	179,000	187,000	198,000 r	200,000	187,000
Apparent:					
Primary	149,000	140,000	147,000	129,000	121,000
Secondary, purchased scrap[4]	36,900	49,400	42,000	59,200 r	69,800
Total	186,000	190,000	189,000	188,000	191,000
Apparent primary plus reported secondary	212,000	211,000	231,000	230,000	221,000
Stocks, yearend:					
Government	2,600	--	--	--	--
Producers and traders	13,100	12,700	12,300	12,600	6,150
Consumer, primary	10,500	4,980	6,400	4,190 r	3,290
Consumer, secondary	5,460	5,070	7,860	9,720	9,420
Total	31,600	22,800	26,600	26,500	18,900
Employment, yearend:					
Mine	7	1 r	1	--	--
Smelter	6	6	(5)	--	--
Port facility	1	1	--	--	--
Price, cash, London Metal Exchange:					
Average annual	4,630	6,011	8,638	5,945	6,772
Average annual dollars per pound	2.100	2.727	3.918	2.696	3.072
World, mine production	1,180,000	1,160,000	1,270,000 r	1,340,000 r	1,340,000 e

[e]Estimated. [r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; except prices; may not add to totals shown.

[2]Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.

[3]More nearly represents amount consumed than does apparent secondary consumption.

[4]Internal evaluation indicates that apparent secondary consumption is considerably understated.

[5]The smelter at Riddle, OR, was decommissioned in 2000.

TABLE 2

NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons of contained nickel)

	2001	2002
Kind of scrap:		
Aluminum-base[2]	3,530 r	3,200
Copper-base	2,480	1,970
Ferrous-base[3]	89,600 r	90,700
Nickel-base	5,200	3,920
Total	101,000	99,800
Form of recovery:		
Aluminum-base alloys	3,530 r	3,200
Copper-base alloys	4,130	3,020
Ferrous alloys	89,600 r	90,700
Nickel-base alloys	3,550	2,860
Miscellaneous and unspecified	2 r	--
Total	101,000	99,800

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Primarily borings and turnings of wrought alloys, such as 2218, 2618, 4032, and 8280, or special casting alloys, such as 203.0.

[3]Primarily stainless and alloy steel scrap consumed at steel mills and foundries.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM[1]

(Metric tons of contained nickel)

Form	2001	2002
Primary:		
Metal	84,000	71,200
Ferronickel	10,500	12,500
Oxide and oxide sinter[2]	1,830	1,710
Chemicals	1,150	740
Other	1,370	1,110
Total	98,800	87,300
Secondary, scrap[3]	101,000	99,800
Grand total	200,000	187,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chemical-grade oxide.
[3]Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4

U.S. CONSUMPTION OF NICKEL IN 2002, BY USE[1]

(Metric tons of contained nickel)

Use	Metal	Ferro-nickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total 2002	Grand total 2001
Cast irons	132	W	--	--	40	172	359	531	886 r
Chemicals and chemical uses	25	--	W	342	--	367	--	367	1,630
Electric, magnet, expansion alloys	130	--	--	--	--	130	W	130	273
Electroplating, sales to platers	12,300	--	--	37	W	12,300	W	12,300	12,500
Nickel-copper and copper-nickel alloys	2,750	--	W	--	15	2,770	2,960	5,720	7,190 r
Other nickel and nickel alloys	11,800	W	W	--	57	11,900	2,020	13,900	17,900 r
Steel:									
Stainless and heat resistant	25,300	12,500	1,620	W	503	39,900	89,600	129,000	121,000
Alloys, excludes stainless	3,170	60	--	--	W	3,230	745	3,980	7,590 r
Superalloys	11,200	--	W	W	393	11,600	534	12,100	18,400
Other[2]	4,440	5	88	361	105	5,000	3,570	8,570	12,200 r
Total	71,200	12,500	1,710	740	1,110	87,300	99,800	187,000	200,000
Total all companies, apparent	XX	XX	XX	XX	XX	121,000	69,800	191,000	188,000

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by the symbol "W."

TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM, DECEMBER 31[1]

(Metric tons of contained nickel)

Form	2001	2002
Primary:		
Metal	3,010 r	2,660
Ferronickel	543	114
Oxide and oxide sinter	268	67
Chemicals	139	241
Other	229	212
Total	4,190 r	3,290
Secondary, scrap	9,720	9,420
Grand total	13,900	12,700

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 6

U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS[1, 2]

Class	2001 Quantity (metric tons of contained nickel)	2001 Value (thousands)	2002 Quantity (metric tons of contained nickel)	2002 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	1,400	$10,000	1,740	$11,400
Ferronickel	50	478	46	879
Powder and flakes	1,380	25,100	1,480	20,600
Metallurgical-grade oxide	1,940	8,370	685	2,830
Chemicals:				
Catalysts	2,560	77,900	1,610	53,800
Salt[3]	1,120	11,700	969	12,500
Total	8,450	134,000	6,520	102,000
Secondary:				
Stainless steel scrap	32,900	270,000	25,700	252,000
Waste and scrap	15,700	55,400	13,700	51,700
Total	48,600	325,000	39,400	304,000
Grand total	57,000	459,000	45,900	406,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	447	7,110	482	6,890
Sheets, strip, foil	1,160	16,900	1,840	23,900
Tubes and pipes	802	3,480	248	2,300
Total	2,400	27,500	2,570	33,100
Alloyed, gross weight:				
Unwrought alloyed ingot	13,400	148,000	8,720	95,200
Bars, rods, profiles, wire	9,550	161,000	7,540	129,000
Sheets, strip, foil	7,180	108,000	6,760	101,000
Tubes and pipes	1,900	32,200	1,770	30,600
Other alloyed articles	3,970	88,200	4,290	104,000
Total	36,000	538,000	29,100	460,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The nickel contents are as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.

[3]Excludes nickel carbonate (more information can be found in the Harmonized Tariff System Schedule B, export commodity code 2836.99.9050).

Source: U.S. Census Bureau.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS IN 2002, BY COUNTRY[1]

(Metric tons of contained nickel)[2]

Country	Cathodes, pellets, and briquets, (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total 2002	Total 2001	Wrought nickel[4]
Australia	(5)	7	--	--	96	3	3	109	91	3
Belgium	(5)	50	--	--	142	90	67	349	830	9
Brazil	168	29	--	1	--	12	43	253	185	1
Canada	194	356	9	617	9,890	2,580	430	14,100	15,200	109
China	--	33	25	--	3	5,170	51	5,280	2,480	19
Colombia	14	4	--	--	--	--	13	31	127	44
Finland	--	(5)	--	--	9	420	19	448	12	(5)
France	117	174	--	1	7	13	31	343	374 r	714
Germany	12	121	(5)	11	514	346	38	1,040	1,850	25
India	11	4	2	--	22	950	10	999	1,920	1
Italy	--	22	--	(5)	--	17	13	52	384	83
Japan	11	69	10	13	1,040	475	268	1,890	3,740	13
Korea, Republic of	25	40	--	1	370	5,700	426	6,570	10,900	29
Mexico	1,150	67	(5)	4	44	73	237	1,570	1,480	1,020
Netherlands	(5)	116	(5)	--	530	26	39	711	1,280	30
South Africa	--	3	--	13	64	--	8	88	358	1
Spain	3	8	--	--	--	1,570	--	1,580	31	160
Sweden	--	41	--	--	555	28	22	646	576	(5)
Taiwan	--	19	--	(5)	24	7,680	115	7,840	11,900	8
United Kingdom	32	54	(5)	19	341	229	11	686	597 r	156
Other	6	258	(5)	5	29	305	730	1,330	2,720	152
Total	1,740	1,480	46	685	13,700	25,700	2,570	45,900	57,000	2,570

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemicals category contains the following: chemical-grade oxide, sesquoxide, and hydroxide, 65%; chlorides, 25%; and sulfate, 22%. Other salts and various catalysts are assumed to be 22% nickel.
[3]Chemical-grade oxide is included in the "Chemicals" category.
[4]Excluded from "Total."
[5]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS[1]

Class	2001 Quantity (metric tons of contained nickel)	2001 Value (thousands)	2002 Quantity (metric tons of contained nickel)	2002 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	111,000	$715,000	97,200	$648,000
Ferronickel	11,600	62,300	12,300	81,200
Powder and flakes	8,310	81,300	6,970	67,900
Metallurgical-grade oxide	1,350	10,700	1,230	8,180
Chemicals:				
Catalysts	1,250	58,800	1,280	41,700
Salt[3]	1,940	21,700	1,590	16,000
Total	136,000	950,000	121,000	864,000
Secondary:				
Stainless steel scrap	3,180	24,100	6,080	49,400
Waste and scrap	5,580	45,900	3,030	18,000
Total	8,760	69,900	9,110	67,400
Grand total	144,000	1,020,000	130,000	931,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	460	5,930	468	6,470
Sheets, strip, foil	358	8,350	296	6,550
Tubes and pipes	317	4,770	115	1,750
Total	1,140	19,000	879	14,800
Alloyed, gross weight:				
Unwrought alloyed ingot	4,110	62,900	2,540	25,100
Bars, rods, profiles, wire	8,880	107,000	7,870	88,400
Sheets, strip, foil	3,080	50,800	3,710	45,600
Tubes and pipes	2,600	40,000	2,850	42,200
Other alloyed articles	1,770	38,300	1,810	39,400
Total	20,400	299,000	18,800	241,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The nickel contents are as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts which are assumed to be 22% nickel. The typical catalyst is assumed to have a nickel content of 22%. Waste and scrap is assumed to be 50% nickel; stainless steel scrap, 7.5% nickel.

[3]Excludes nickel carbonate (more information can be found at Harmonized Tariff Schedule of the United States subheading 2836.99.5000).

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY[1]

(Metric tons of contained nickel)[2]

Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total		Wrought nickel[4]
								2002	2001	
Australia	9,370	932	--	38	34	--	23	10,400	17,200	3
Austria	--	(5)	--	--	6	--	--	6	22	155
Belgium	--	25	--	--	60	--	231	316	683	(5)
Brazil	722	--	93	--	27	--	1	842	3,380	5
Canada	48,200	4,420	--	1,190	944	4,210	440	59,400	60,700	(5)
China	--	4	--	--	--	(5)	99	103	92	2
Colombia	--	--	2,470	--	6	70	--	2,550	1,950	--
Dominican Republic	--	--	6,720	--	--	3	--	6,720	4,390	--
Finland	3,710	532	--	--	--	--	395	4,640	8,770	--
France	1,330	1	--	--	679	10	281	2,300	4,340	88
Germany	360	286	--	--	176	--	342	1,160	1,670	374
Japan	(5)	20	2	1	47	8	395	473	595	111
Mexico	--	--	--	--	5	1,450	9	1,470	1,080	--
Netherlands[6]	112	1	19	--	(5)	--	399	531	757	1
New Caledonia	--	--	1,100	--	--	--	--	1,100	3,350	--
Norway	8,520	--	--	--	28	--	1	8,550	18,900	--
Russia	23,300	432	449	--	32	--	1	24,200	9,280	--
South Africa	254	101	--	--	1	(5)	--	356	366	--
United Kingdom	223	137	(5)	--	662	11	123	1,160	2,560	61
Venezuela	--	--	1,480	--	4	205	--	1,690	1,920	--
Zimbabwe	1,140	--	--	--	--	--	--	1,140	932	(5)
Other	18	84	--	--	319	107	122	650	1,410	79
Total	97,200	6,970	12,300	1,230	3,030	6,080	2,860	130,000	144,000	879

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The chemicals category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel. Waste and scrap is assumed to be 50% nickel, and stainless steel scrap, 7.5% nickel.

[3]Primarily oxide, rondelles, and sinter.

[4]Excluded from "Total."

[5]Less than 1/2 unit.

[6]The different nickel metal products (cathode, powder, etc.) are apparently material that has transited through bonded warehouses in the Netherlands, including warehouses overseen by the London Metal Exchange.

Source: U.S. Census Bureau.

TABLE 10

NICKEL: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of nickel content)

Country	1998	1999	2000	2001	2002
Australia, content of concentrate	143,513	119,226	165,700	197,000	211,000 p
Botswana, content of ore milled	21,700	33,733	20,286 r	18,585 r	20,005
Brazil, content of ore	36,764	41,522	45,317	47,097 r	45,029
Burma, content of ore	30	76	40	40 e	30 e
Canada, content of concentrate	208,301 r	186,236	190,793	194,058 r	178,338 p
China[e]	48,700	49,500	50,300	51,500	54,500
Colombia, content of laterite ore	29,422	39,274	58,927	52,962	58,196
Cuba, content of oxide, oxide sinter, oxide powder, sulfide, ammoniacal liquor[3]	64,605 r	63,508 r	67,754 r	72,620 r	73,000 e
Dominican Republic, content of laterite ore	40,311	39,997	39,943	39,120 r	38,859
Finland, content of concentrate	1,967	70	3,347 r	2,200 r	2,500
Greece, content of laterite ore	16,985	16,050	19,535	20,830	22,670
Indonesia, content of laterite ore	74,063	89,111	98,200	102,000	122,000 e
Kazakhstan, content of laterite ore[e]	--	--	30	3,200	3,000
Macedonia, content of ferronickel produced[e]	5,800	1,900	--	3,100 r	5,100
New Caledonia, content of ore	125,319	110,062	128,789	117,554	99,650 p
Norway, content of concentrate[4]	2,959	2,965	2,538	2,529 r	1,700
Philippines, content of ore	23,713	20,689	17,388	27,359	26,532 p
Russia, content of ore[e]	290,000	300,000	315,000	325,000	310,000
Serbia and Montenegro, content of ferronickel produced	466	--	--	--	--
South Africa, content of concentrate	36,679	36,202	36,616	36,443	38,546
Ukraine, content of laterite ore	--	--	--	1,500	2,000
Venezuela, content of laterite ore	--	--	2,540	13,600	18,200 e
Zimbabwe, content of concentrate	12,872	11,164	8,160	10,120 r	8,092
Grand total	1,180,000	1,160,000	1,270,000 r	1,340,000 r	1,340,000
Of which:					
Content of concentrate	406,000	356,000	407,000	442,000	440,000
Content of ore and ore milled	498,000	506,000	527,000	536,000	501,000
Content of laterite ore	161,000	184,000	219,000	233,000	265,000
Content of ferronickel produced	6,270	1,900	--	3,100	5,100
Content, unspecified and/or undifferentiated	113,000	113,000	118,000	124,000	128,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this is noted parenthetically. North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Table includes data available through July 29, 2003.

[3]The Government of Cuba reports plant production on a contained nickel plus cobalt basis. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt. The cobalt content was determined to be 1.16% for granular and powdered oxide, 1.21% for oxide sinter, 7.56% for sulfide precipitate, and 33% for leach ammoniacal precipitate.

[4]A/S Nikkel Og Olivin halted mining operations in October 2002.

TABLE 11

NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of nickel content)

Country and product[3]	1998	1999	2000	2001	2002
Australia:					
Metal	64,322	75,952	99,400	117,000	133,000 p
Unspecified	15,256	7,648	9,155	10,000	10,000 p
Total	79,578	83,600 [4]	108,555 [4]	127,000	143,000 p
Austria, ferronickel[e]	1,800	1,700	1,700	1,600	1,500
Brazil:[5]					
Ferronickel	8,077	6,502	6,347	5,768 r	6,011
Metal	13,006	16,429	16,906	17,663 r	17,676
Total	21,083	22,931	23,253	23,431 r	23,687
Canada, unspecified[6]	146,755 r	124,260	134,225	140,591 r	144,476
China, metal[e]	40,100	44,400	50,900	49,500	54,000
Colombia, ferronickel	28,185 r	28,265 r	27,736 r	38,446 r	43,987
Cuba, oxide sinter and oxides[7]	38,192	37,510	39,228 r	40,748	39,516
Dominican Republic, ferronickel	25,220	24,455 r	27,829	24,005 r	23,303
Finland:					
Metal	46,200	51,948	50,087 r	51,275 r	56,600
Chemicals	4,518	4,143	3,711	3,700	3,600
Total	50,718	56,091	53,798 r	54,975 r	60,200
France:					
Metal	9,778	9,458	10,100	11,033	9,440 e
Chemicals	2,000 e	2,244	2,176	2,000	2,000 e
Total[8]	11,778	11,702	12,276	13,033	11,444
Greece, ferronickel	15,005	12,964	17,470	17,675	17,700 e
Indonesia, ferronickel	8,451 r	9,385 r	10,111	10,302	8,804
Japan:					
Ferronickel	69,202	67,166	74,753	69,112	74,200 e
Metal	29,397	30,481	36,230	32,526	32,300
Oxide sinter	25,435	34,482	47,020	49,600	47,500 e
Chemicals	2,511	2,570	2,700	2,400	1,820
Total	126,545	134,699	160,703	153,638	156,000 e
Korea, Republic of, metal	(9)	(9)	(9)	(9)	(9)
Macedonia, ferronickel[e]	5,800	1,900	--	3,100 r	5,100
New Caledonia, ferronickel	44,491	45,289	43,914	45,912	48,650 p
Norway, metal	70,152	74,137	58,679	68,221 r	68,530
Poland, chemicals[10]	376	396	430	480 r	450
Russia:[e, 11]					
Ferronickel	7,000 r	9,000	7,000	8,000	8,000
Metal	208,000 r	215,000	225,000	230,000	219,000
Oxide sinter	10,000 r	12,000	14,000	12,000	10,000
Chemicals	2,000	2,000	2,000	2,000	2,000
Total	227,000	238,000	248,000	252,000	239,000
Serbia and Montenegro, ferronickel	466	--	--	--	--
South Africa:					
Metal	29,039	28,345	30,900	30,500	31,600 e
Chemicals[12]	7,640	7,855	5,720 e	5,940 e	7,900 e
Total	36,679	36,200	36,616	36,443	39,546
Taiwan, metal	(9)	(9)	(9)	(9)	(9)
Ukraine, ferronickel[e]	--	--	650	2,500	6,000
United Kingdom, metal	41,994	39,467	37,976	33,817	33,790
United States, ferronickel	4,290	--	--	--	--
Venezuela, ferronickel	--	--	40	9,700	15,500 e
Zimbabwe, metal:					
Refined from domestic materials[13]	8,732	9,106	6,678 r	7,440	8,092
Toll refined from imported materials[14]	8,709	10,676	12,931	12,084	13,600 e
Total	17,441	19,782	19,609 r	19,524	21,692

See footnotes at end of table.

TABLE 11--Continued

NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of nickel content)

Country and product[3]	1998	1999	2000	2001	2002
Grand total	1,040,000	1,050,000	1,110,000	1,170,000 r	1,210,000
Of which:					
Ferronickel	218,000 r	207,000	218,000	236,000 r	259,000
Metal	569,000 r	605,000	636,000	661,000 r	678,000
Oxide sinter	73,600 r	84,000	100,000 r	102,000	97,000
Chemicals	19,000	19,200	16,700	16,500 r	17,800
Unspecified	162,000	132,000	143,000	151,000	154,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 29, 2003.

[3]In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate to make reliable estimates of output levels. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries producing matte for export are listed in table 12.

[4]Includes estimated production of pressure acid leach operations.

[5]Brazil produced nickel carbonate (an intermediate product), in metric tons: 1998--13,952; 1999--17,153; 2000--17,223; 2001--17,063 (revised); and 2002--17,000 (estimated).

[6]Nickel contained in products of smelters and refineries in forms, which are ready for use by consumers. Figures include the nickel content of nickel oxide sinter exported to the Republic of Korea and Taiwan. More information can be found in footnote 8.

[7]Cuba also produces nickel sulfide, but because it is used as feed material elsewhere, it is not included to avoid double counting. Combined output of processed sulfide and ammoniacal liquor precipitate was, as follows, in metric tons of contained nickel: 1998--26,413; 1999--25,998; 2000--28,526 (revised); 2001--31,872 (revised); and 2002--77,600 (estimated). More information can be found in table 12.

[8]Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.

[9]Nickel metal production for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical-grade oxides and to include them would result in double counting. Metal estimates are as follows, in metric tons: Republic of Korea: 1998--20,183; 1999--20,235; 2000--29,890; 2001--30,580 (revised); and 2002--31,000; and Taiwan: 1998--10,500; 1999-2000--10,000; 2001--11,500; and 2002--11,000.

[10]Nickel content of nickel sulfate ($NiSO_4$~$6H_2O$). Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.

[11]Includes production from sulfidized concentrates shipped from Cuba for toll refining.

[12]Includes nickel sulfate plus exported metal in concentrate.

[13]Data represent production from domestic nickel ore.

[14]Previously published as "Other, metal." Data represent production from imported Botswanan matte as well as from South African nickel sulfate.

TABLE 12

NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY[1, 2]

(Metric tons of nickel content)

Country	1998	1999	2000	2001	2002
Matte:					
Australia[3]	47,459	28,190	41,771	34,978	40,000 e
Botswana	22,851	22,898	21,446	22,454	23,896
Brazil[4]	4,670	9,306	8,475	10,249 r	6,274
Canada[e, 5]	48,000	52,000	37,000	49,000	50,000
China[e, 6]	--	1,210	430	76	--
Indonesia	35,697	45,400	59,200	63,471 r	60,300 p
New Caledonia	12,011	11,353	13,549	13,061	11,217 p
Russia[e, 7]	98	114	517	97	9
Total	171,000	170,000 r	182,000	193,000 r	192,000
Other, Cuba:[8]					
Sulfide precipitate	25,176	24,999	27,288	29,914 r	30,858
Ammoniacal liquor precipitate	1,237	999	1,238 r	1,958	1,218
Total	26,413	25,998	28,526 r	31,872 r	32,076

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]Table includes data available through July 29, 2003. Data represent nickel content of matte and other intermediate materials produced for export.

[2]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[3]Total matte production on a contained nickel basis, in metric tons, was as follows: 1998--100,071; 1999--79,668; 2000--103,019 (revised); 2001--96,550 (revised); and 2002--91,574. Figures exclude toll-refined material.

[4]Represents the output of the Fortaleza smelter. All of the Fortaleza matte is being shipped to Finland for further processing.

[5]Estimated nickel content of reported exports.

[6]Chinese exports were estimated to have a nickel content of 63%. Total matte production on a contained nickel basis, in metric tons, was estimated to be as follows: 1998--47,000; 1999--50,100; 2000--57,000; 2001--59,000; and 2002--60,000.

[7]Russian export figures reported primarily by the importing countries of France and Norway. Russian exports to Norway were estimated to have a nickel content of 40%.

[8]Corrected for coproduct cobalt.

TABLE 13

NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2015

Projected first year of production	Country and State/Province	Project and company	Resource grade (percentage of nickel)	Estimated resources (thousand metric tons)[1]	Annual production capacity of contained nickel (metric tons)	Nickel product
2004	Turkey, Manisa	Caldag, European Nickel plc.	1.40	44,000	20,000	Ore and concentrate.
2005	Philippines, Mindanao	Adlay, BHP Billiton plc.	1.61	6,000	5,000	Ore.
2005	Philippines, Palawan	Rio Tuba, Coral Bay Nickel Corp.	1.26	16,000	10,000	Ni-Co sulfide.
2006	Australia, Western Australia	Ravensthorpe, BHP Billiton plc.	0.80	150,000	45,000	Ni-Co hydroxide.
2006	New Caledonia	Goro, Inco Ltd., Bureau de Recherches Geologiques et Minieres, and Sumitomo consortium	1.57	200,000	55,000	Ni oxide.
2007	Madagascar	Ambatovy, Dynatec Corp. and Phelps Dodge Corp.	1.10	210,000	50,000	Metal.
2007	New Caledonia	Koniambo, Falconbridge Ltd. and Societe Miniere du Sud Pacifique S.A.	2.57	150,000	60,000	Ferronickel.
2008	Brazil, Para	Vermelho, Companhia Vale do Rio Doce	1.23	220,000	45,000	Metal or oxide.
2009	Do.	Onca-Puma, Canico Resource Corp.	2.22	33,000	25,000	Matte or oxide.
2009	Cuba, Holguin	Pinares de Mayari West, Government of Cuba	1.10	200,000	40,000	Metal or oxide.
2009	Indonesia, Maluku	Gag Island, BHP Billiton plc. and PT Aneka Tambang	1.35	240,000	30,000	Intermediate, metal, or ferronickel.
2010	Cuba, Camaguey	San Felipe, BHP Billiton plc. and Government of Cuba	1.30	250,000	45,000	Metal or oxide.
2010	Indonesia, Halmahera Island	Weda Bay, Weda Bay Minerals, Inc. and PT Aneka Tambang	1.35	220,000	48,000	Ni-Co sulfide.
2010	New Caledonia	Nakety-Bogota, Argosy Minerals, Inc. and Societe des Mines de la Tontouta	1.47 1.50	88,000 140,000	52,000	Ni-Co intermediate.
2011	Australia, Western Australia	Mount Margaret, Anaconda Nickel Ltd.	0.78	170,000	45,000	Ni-Co hydroxide.
2012	Australia, New South Wales	Syerston, Black Range Minerals Ltd.	0.65	96,000	18,000	Ni-Co sulfide concentrate.
2012	Australia, Queensland	Marlborough, Preston Resources Ltd.	1.02	210,000	25,000	Metal.
2013	Papua New Guinea	Ramu River, Highlands Pacific Ltd. and Orogen Minerals Ltd.	0.91 1.01	76,000 67,000	33,000	Do.
2013	Philippines, Mindoro Island	Sablayan, Crew Development Corp.	0.94	72,000	40,000	Do.
2014	Australia, Western Australia	North Kalgoorlie—Ghost Rocks, Goongarrie, and Kalpini, Heron Resources Ltd.	1.24	110,000	45,000	Concentrate.
2015	Brazil, Goias	Barro Alto, Anglo American plc.	1.20	120,000	40,000	Ferronickel.
2015	Cote d'Ivoire	Biankouma, Touba, and Sipilou, Falconbridge Ltd. Societe d'Etat pour le Developpement Minier	1.48	260,000	45,000	Ni-Co intermediate or ferronickel.
2015	Papua New Guinea	Wowo Gap, Resource Mining Corp. Ltd.	1.09 1.44 1.02	31,000 18,000 18,000	45,000	Metal.

[1]Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits.

Sources: Company annual reports, presentations, and press releases; CRU International, Ltd.

TABLE 14

NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2015

Projected first year of production	Country and state/province	Project and company	Resource grade (percentage of nickel)	Estimated resources (thousand metric tons)[1]	Annual production capacity of contained nickel (metric tons)	Nickel product
2002	Zimbabwe, Mhondoro region	Ngezi platinum, Makwiro Platinum Mines (Pvt.) Ltd. and Zimbabwe Platinum Mines Ltd.	0.12	32,000	1,300	Matte.
2003	Australia, Western Australia	Cosmos Deeps, Jubilee Mines NL	7.20	520	10,000	Concentrates.
			3.90	110		
2004	Do.	Forrestania-New Morning and Diggers South, Western Areas NL	1.63	3,000	3,000	Do.
2004	Do.	Maggie Hays, LionOre Australia Ltd.	1.47	12,000	(2)	Do.
2004	Do.	Sally Malay, Sally Malay Mining Ltd.	1.80	4,000	8,000	Do.
2004	Canada, Ontario	McCreedy West/Levack, FNX Mining, Inc. and Dynatec Corp.	1.91	1,200	7,000	Ore.
			1.90	2,700		
			1.80	2,400		
2004	Spain, Extramadura Province	Aguablanca, Rio Narcea Gold Mines Ltd.	0.67	23,000	10,000	Concentrates.
2005	Canada, Ontario	Montcalm, Falconbridge Ltd.	1.48	7,700	8,000	Do.
2006	Canada, Labrador	Voisey's Bay, Inco Ltd.	2.88	31,000	50,000	Concentrates, initially.
			1.29	97,000		
			0.98	14,000		
2007	Canada, Ontario	Norman, FNX Mining, Inc. and Dynatec	0.95	(3)	NA	Ore.
2008	Australia, Western Australia	Honeymoon Well, Mining Project Investors Pty. Ltd. and OM Group, Inc.	0.82	140,000	30,000	Concentrates, initially.
2008	Do.	Yakabindie, WMC Ltd.	0.56	290,000	32,000	Ore.
2008	Canada, Ontario	Nickel Rim South, Falconbridge Ltd.	1.70	6,300	10,000	Concentrates.
2008	United States, Minnesota	Mesaba, Teck Cominco American, Inc.	0.12	300,000	20,000	Byproduct concentrate of Ni-Co sulfide or hydroxide.
2009	Tanzania, Kagera region	Kabanga, Barrick Gold Corp.	2.18	21,000	17,000	Concentrates.
2011	Canada, Manitoba	Maskwa, Canmine Resources Crop.	1.27	2,900	3,800	Do.

NA Not available.

[1]Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits.

[2]The massive sulfide ores at Maggie Hays would be shipped to the neighboring Emily Ann concentrate plant. The concentrate plant would be upgraded to 500,000 metric tons per year of ore to handle the additional feed.

[3]Resource estimate in progress.

Sources: Canadian Minerals Yearbook 2000; company annual reports, presentations, and press releases; and CRU International, Ltd.